Ciments Canada Lafarge Ltée
Canada Cement Lafarge Ltd.

Energy Conservation in the
Industrial Minerals Processing Sector
Comminution (Crushing and Grinding) Phase III

Activity 5
Wet Comminution of Asbestos

Kilborn Limited

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PHASE III

ACTIVITY 5

Wet Comminution of Asbestos

ENERGY CONSERVATION IN THE INDUSTRIAL MINERALS PROCESSING SECTOR

COMMINUTION (CRUSHING AND GRINDING) PHASE III

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WET COMMINUTION OF ASBESTOS

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ENERGY CONSERVATION IN THE INDUSTRIAL MINERALS PROCESSING SECTOR

COMMINUTION (CRUSHING AND GRINDING) PHASE III

ACTIVITY 5

WET COMMINUTION OF ASBESTOS

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A) ORF Report
B) Conceptual Layouts and Details of Cost Estimates

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1.0 EXECUTIVE SUMMARY

Kilborn Limited was requested to carry out an Energy Conservation Study on the Wet Communition of Asbestos by pilot plant investigation. This investigation was to lead to a capital, operating and energy cost comparison of asbestos wet and dry milling processes.

Pilot plant work was carried out by the Ontario Research Foundation (ORF) and beneficiated ore samples were supplied by Lac d'Amiante de Québec (LAQ). The objective of the pilot plant study was to evaluate four (4) communition mills and to select the most suitable "grinding" media for asbestos ore, consistent with fiber quality and fibre recovery.

The information from the pilot plant testing was used to revise the conceptual design of a dry and a wet processing plant, rated at a production of 30,000 tonnes of fibre per year, which was judged to be the dry plant break-even design under todays marketing conditions. The mill feed is assumed to be beneficiated asbestos ore containing about 5.0% recoverable fibre.

Due to the fact that the flowsheet was based on test work carried out on laboratory scale equipment and other preliminary data, Kilborn had to make various scale-up assumptions for the study. These assumptions will have to be verified through further research.

Pilot Plant Work

Four (4) communition mills were tested namely:

Ball Mill
Rod Mill
Attrition Mill
Szego Mill.

The Rod Mill showed to be the best suitable equipment regarding fibre quality and fibre recovery. The energy consumption determined during the pilot plant work is, due to expected scale-up problems, not used in the conceptual design of the wet mill. A calculation using a Bond's Work Index of 18.15 has been used.

Comparison of Fibre Recovery and Fibre Quality

The pilot plant testing of the wet circuit has indicated that the circuit produces a greater fibre recovery (6.9% versus 5.2%) of slightly shorter fibre which however is cleaner and stronger.

Process Flowsheets

The dry process flowsheet of the beneficiated ore feed follows standard dry milling techniques of screening and air lifting with three stages of impact crushing. Fibre cleaning and fibre opening is done with standard screening, fibre opening and fibre dedusting equipment. Fibre is produced at 1% moisture.

The wet process flowsheet contains one stage of communition, two stages of fibre recovery (in elutriation cones) and three stages of fibre cleaning, i.e. two stages of washing trommels and one stage of gravity tables. Fibre product and fine tailings are dewatered in filter presses. The fibre product is dried to 1% moisture.

Capital Cost

Order of magnitude capital costs for the two process plants were estimated as follows:

Dry mill	$20.5 million
Wet mill	$15.8 million

The normal contingency of 10% for the dry mill is increased to 25% for the wet process mill, to reflect the more conceptual nature of the design.

Operating Cost

Order of magnitude annual operating costs of the two plants were estimated at:

Dry mill	$ 7.5 million
Wet mill	$ 6.2 million

(The mining cost and ore beneficiation cost are not included.)

Energy Consumption (figure 1.1 page 1-4)

Fuel used for drying is the major item of energy consumption. The wet mill uses slightly less than the dry mill (68.5% of total consumption versus 71.7%).

Energy used in crushing (including communition and auxiliaries) amounts only to 1.3% of the total energy consumed for the dry mill and 1.9% for the wet mill.

Aspiration and dust control energy consumption are greatly reduced in the wet mill (7.7% versus 1.3%) as would have been expected.

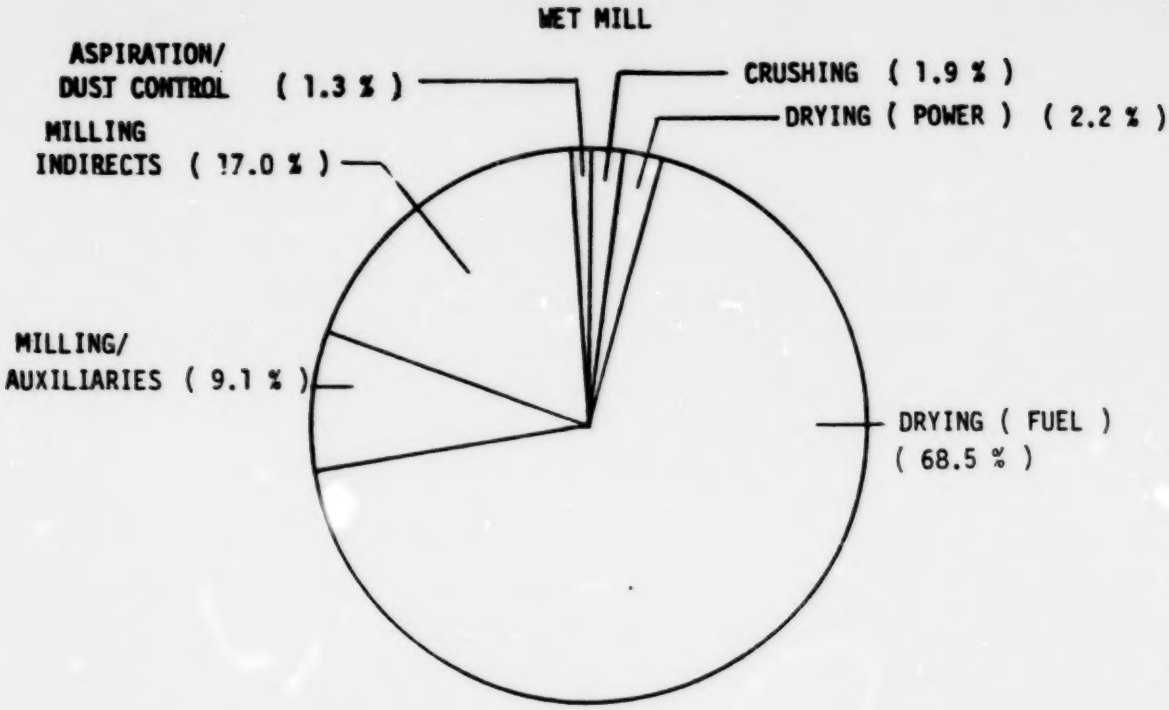
Conclusions

It should be mentioned that the order of magnitude calculations are based on several scale-up assumptions, nevertheless the study has shown that:

- No substantial savings in Kwh can be expected from cummunition of asbestos by wet milling.
- A modest saving is possible in total power consumption of a wet mill over a dry mill installation.

Illustrated in figure 1.2 (page 1-5) it can be seen that:

- Energy savings are possible in the dryer fuel consumption in the wet mill.
- Substantial savings in capital cost and operating cost are possible in the wet mill.
- Additional research on large scale fibre recovery equipment and drying equipment is justified.



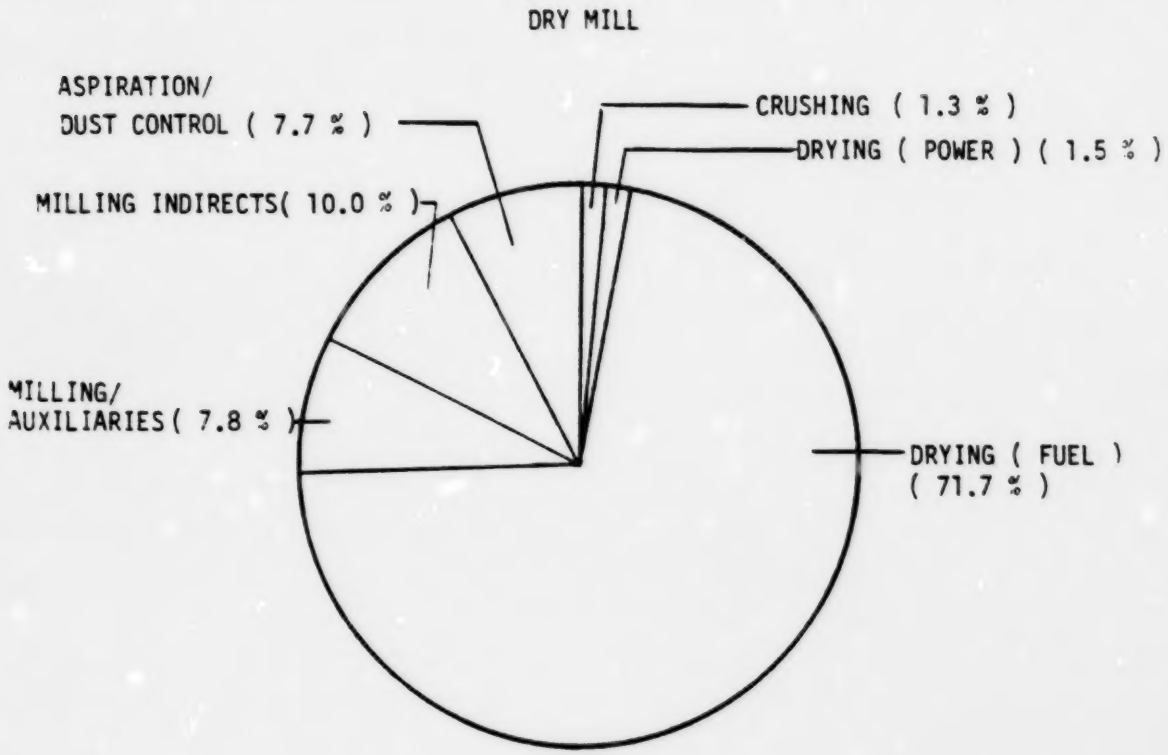

DRY MILL
ASPIRATION/
DUST CONTROL (7.7 %)
CRUSHING (1.3 %)
DRYING (POWER) (1.5 %)
MILLING INDIRECTS(10.0 %)
MILLING/
AUXILIARIES(7.8 %)
DRYING (FUEL)
(71.7 %)

FIGURE 1.1

DISTRIBUTION OF

TOTAL ENERGY CONSUMPTION

TOTAL ENERGY, CAPITAL & OPERATING COST

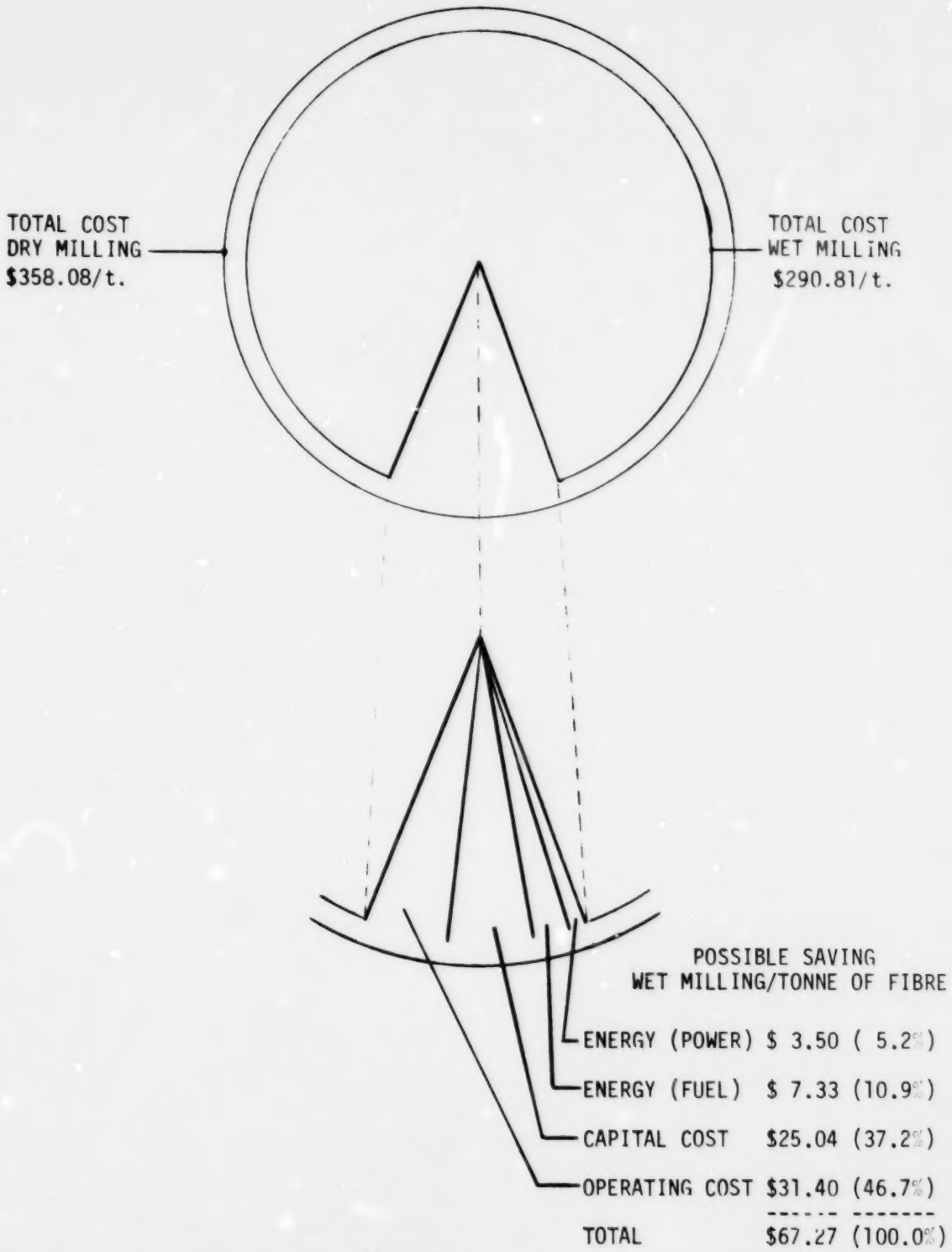


FIGURE 1.2
COMPARISON OF COSTS

1.0 SOMMAIRE

Kilborn Limited a été mandaté pour préparer une étude de Conservation de l'Energie du broyage par voie humide de l'Amiante par des investigations dans une usine pilote.

Les résultats de l'étude devaient être utilisées pour fin de comparaison des coûts d'investissement, des coûts d'exploitation et des coûts énergétiques entre une usine de traitement par voie humide et sec de l'amiante.

Les travaux de l'usine pilote ont été faits par l'Ontario Research Foundation (ORF) et les échantillons du minerai bénéficié ont été fournis par Lac d'Amiante du Québec (LAQ). L'objectif des travaux de l'usine pilote était l'évaluation de quatre (4) type de broyeurs et la sélection de la meilleure méthode de broyage de l'amiante tout en tenant compte de la qualité de la fibre et sa récupération.

L'information obtenue a été utilisée pour reviser le schéma conceptuel de l'usine par traitement sec et de l'usine de traitement humide produisant 30 000 tonnes métriques de fibre d'amiante par année, ce qui devait représenter le seuil de rentabilité d'une usine de traitement à sec selon la situation du marché d'aujourd'hui. L'alimentation de l'usine pilote provenait du minerai d'amiante bénéficié, contenant environ 5% de fibre récupérable.

Parce que le schéma de traitement humide fut préparé basé sur les travaux exécutés en laboratoire avec de l'équipement miniature et que les résultats ne sont que préliminaires, plusieurs hypothèses ont été élaborées pour faire la conception de l'usine de traitement humide. Ces hypothèses devront donc être vérifées par des recherches plus avancées.

Travaux usine pilote

Quatre (4) broyeurs ont été analysés:

Broyeur à boulets
Broyeur à barres
Broyeur de l'attrition
Broyeur de Szego

Le broyeur à barres a produit les meilleurs résultats relativement à la qualité et la récupération de fibre.

La consommation de l'énergie déterminée pendant les travaux de l'usine pilote n'a pas été utilisée pour le schéma conceptuel en raison de problèmes d'estimation pour des broyeurs plus gros. Un calcul a été fait avec un Index de Bond de 18.15.

Comparaison de la récupération et la qualité de la fibre

Les travaux de l'usine pilote par le procédé de traitement humide ont indiqué que le circuit produit une plus grande récupération (6.9% versus 5.2%) de fibres légèrement plus courte qui est toutefois plus propre et plus forte.

Schéma de traitement

Le schéma de traitement à sec du minerai d'amiante bénéficié suit une technique d'usinage standard de tamisage et de récupération avec trois étapes de concassage à impact. Le nettoyage et l'ouverture de la fibre se fait par l'équipement standard de tamisage, d'ouverture et de dépoussiérage. La fibre produite contient 1% d'humidité.

Le schéma de traitement humide comprend une étape de broyage, deux étapes de récupération de la fibre en utilisant des cônes séparateurs et trois étapes de nettoyage, c'est-à-dire deux étapes à l'aide de trommel de lavage et une étape à l'aide de tables gravimétriques. La fibre et les résidus fins sont passés dans des filtres presse pour enlever l'eau. La fibre est ensuite asséchée à un niveau de 1% d'humidité.

Coûts d'investissement

L'ordre de grandeur du coût d'investissement des deux usines de traitement fut estimé comme suit:

Usine de traitement à sec	$20.5 millions
Usine de traitement humide	$15.8 millions

L'allocation normale de 10% pour les imprévus de construction d'usine de traitement à sec a été majorée à 25% pour l'usine de traitement humide pour tenir compte de l'état conceptuel de son développement.

Coût d'exploitation

L'ordre de grandeur des coûts annuels d'exploitation des deux usines fut estimé comme suit:

Usine de traitement à sec	$ 7.5 millions
Usine de traitement humide	$ 6.2 millions

(Les coûts de minage et la bénéficiation ne sont pas inclus.)

Consommation de l'énergie (figure 1.1 page 1-4)

Le carburant pour le séchage est l'item principal de la consommation. L'usine de traitement humide en utilise un peu moins que l'usine de traitement sec (68.5% de la consommation totale en comparaison de 71.7%).

L'énergie utilisée pendant le broyage (les machines auxiliaires incluses) est seulement 1.3% des consommations totales pour l'usine de traitement sec et 1.9% pour l'usine de traitement humide.

L'énergie utilisée pour l'aspiration et le contrôle de la poussière est réduite tel que prévu dans l'usine de traitement humide (7.7% en comparaison de 1.3%).

Conclusions

On doit mentionner que l'ordre de grandeur des calculs est basée sur plusieurs hypothèses, néanmoins l'étude démontre que:

- Il n'y a pas de grandes économies de Kwh pour le broyage dans une usine de traitement humide.
- Une économie modeste est possible pour la consommation de l'énergie totale dans une usine de traitement humide en comparaison d'une usine de traitement sec.

A la figure 1.2 (page 1-5) il est illustré que:

- Une économie de l'énergie est possible dans la consommation du carburant pour le séchage dans l'usine de traitement humide.
- Les économies considérables sont possibles dans les coûts d'investissement et les coûts d'exploitation dans l'usine de traitement humide.
- Des recherches additionnelles sur des équipements à l'échelle de production pour la récupération de la fibre et du séchage sont justifiées.

2.0 INTRODUCTION

In September of 1985, Kilborn was requested by Canada Cement Lafarge Ltd. to carry out an Energy Conservation study on the Wet Comminution of Asbestos through pilot plant investigations. These investigations were to lead to capital, operating and energy cost comparisons of wet milling and dry milling.

The pilot plant work was carried out by the Ontario Research Foundation (ORF) under the direction of a steering Committee, consisting of representing members of Canada Cement Lafarge Ltd. (CCL); Canada Centre for Mineral and Energy Technology (CANMET); Ontario Research Foundation (ORF) and Kilborn.

Many wet milling flowsheet development aspects were investigated during the pilot plant test work. Kilborn's asbestos processing experience was used in the preliminary designs of dry and wet processing plants. Various scale-up assumptions were made in the development of the conceptual layout of the wet mill, and these require confirmation, however, the designs are valid, for comparison purposes.

3.0 SCOPE OF STUDY

Kilborn's mandate consisted of optimizing the comminution of asbestos ores in terms of direct and indirect energy consumption, by starting with the use "state-of-the-art" wet milling technology, with respect to the needs of asbestos ore comminution.

Size reduction is not the most important processing requirement in the production of asbestos, but fibre release, consistent with fibre quality, is the governing criterion. The scope of the study was therefore adjusted to include this most important criterion. The objective was to evaluate the use of wet comminution as a means of reducing energy consumption when compared to dry milling.

The investigation was to provide an optimization of wet milling techniques by the selection of the most suitable grinding equipment for asbestos ore, consistent with fibre quality and fibre recovery.

The developed information was to be used to complete the design of two mills, one dry and one wet, of identical outputs, for the estimation of capital and operating costs, including the costs of energy.

The development of asbestos processing mills of identical output was to ensure a fair comparison between wet and dry methods in terms of energy, operating and capital costs.

4.0 METHODOLOGY

The laboratory investigations, bench and pilot plant scale at ORF, provides information relative to equipment choice, reduction rates, fibre recovery and quality, energy consumption etc.

The determination of direct communition energy requirements were used in the determination of total potential power savings of wet milling versus dry milling of asbestos.

The approach to the study was to use ORF generated data on wet milling, in a comparison, with dry milling data from Lac d'Amiante du Québec Ltée (LAQ), related to fibre recovery and fibre quality. The main purpose of the pilot plant investigations was the optimization of the comminution method by flowsheet development and equipment selection. This in turn provided a basis for a scaled-up conceptual design of the wet mill.

Kilborn has enlisted the cooperation of LAQ in obtaining representative samples, correlatable with production results, thereby providing a basis for recovery and quality comparisons.

For the comparative study of the capital and operating costs of dry and wet milling, an earlier Kilborn study on wet milling of dry mill tailings was updated and revised to include ORF data on processing of beneficiated ore. Design revisions to the dry and wet mill flowsheets of this earlier report were made to convert both the conceptual processing plants for treatment of beneficiated ore.

The basis for dry milling energy consumption were the findings of phase I of the Energy Conservation Study (The Asbestos Industry, Plant Studies) presented in table 19, page 32 of that study (reproduced in section 6.0). The averages were reconciled to include all energy i.e. drying and milling indirects.

Kilborn was requested to prepare a comparison of all costs; energy (electrical and fuel) capital and operating costs, to determine potential benefits of wet milling over dry milling of asbestos.

5.0 PILOT PLANT INVESTIGATIONS

ORF provided a comprehensive report on its pilot plant activities, including a large amount of preliminary work to optimize the "state-of-the-art" technology of wet processing of asbestos. The investigations have been complex and lengthly and include many laboratory and bench tests, leading to final selection of equipment and a continuous pilot plant run of the selected comminution equipment. The ORF report is written in chronological order and is presented as Appendix A to this report.

Following in this section is a summary of the report. Tables used in this write-up are taken from the ORF report and have the same numbers. The investigations were divided in five main events, namely:

- Ore Selection and Sampling
- Preliminary Testing
- Studies of Retention Time and Percentage Solids
- Bench Scale Testing of Four Grinding Mills
- Pilot Scale Testing of Two Grinding Mills

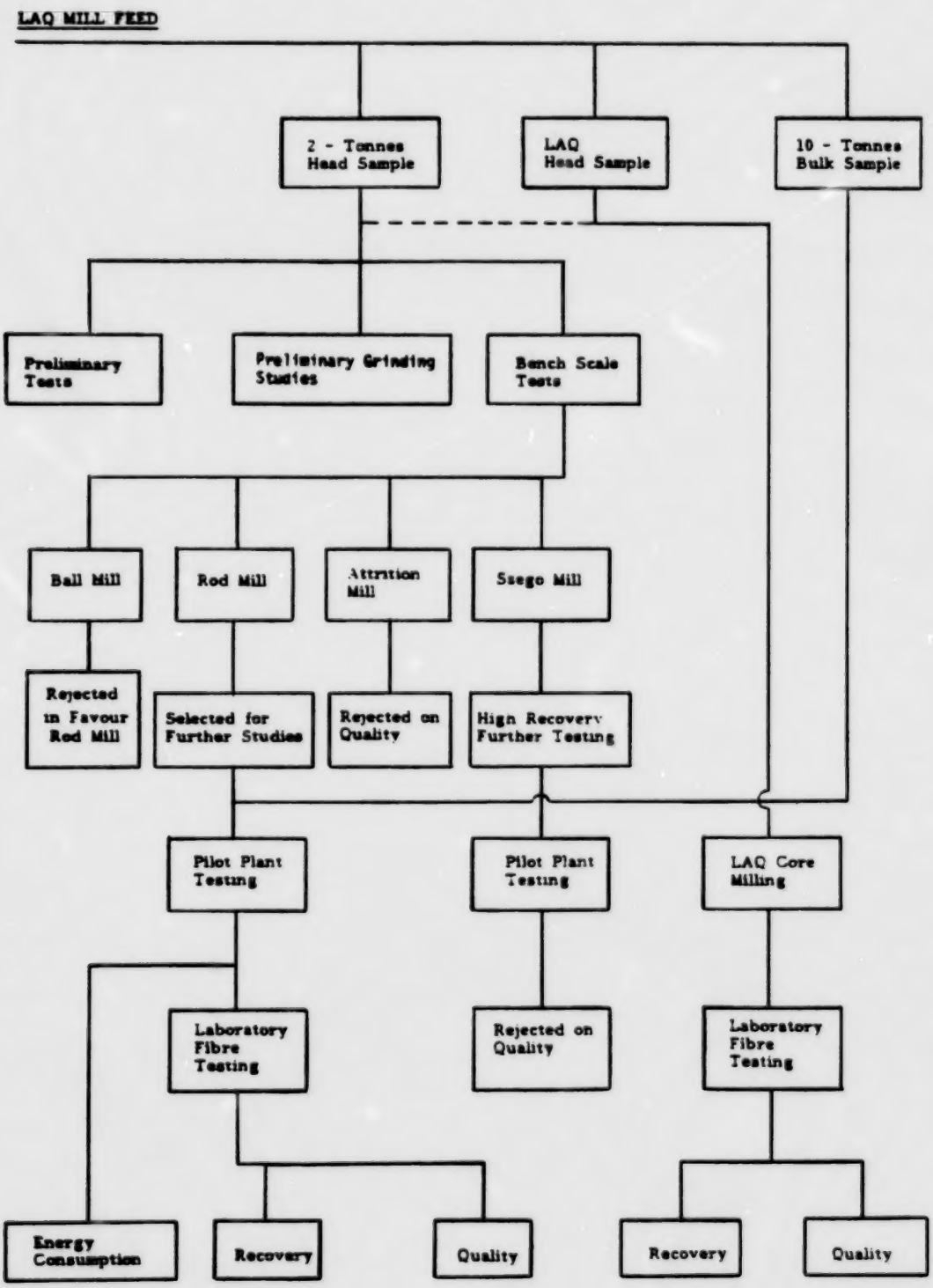
A schematic presentation of the investigations and events is presented in figure 5.1.

5.1 ORE SELECTION AND SAMPLING (ORF report section 2.0)

Arrangements were made with LAQ to provide an adequate amount of ore sample with a quality representative of the dry mill production. The sample was a two-tonne head sample, collected over a number of days and a ten-tonne sample, collected at one time, to supply the ORF with adequate grinding feed for the pilot plant tests. Details of the disposition and sampling of these quantities are reported in section 2 of the ORF report.

FIGURE 5.1

SCHEMATIC PRESENTATION OF INVESTIGATIONS



5.2 PRELIMINARY TESTING (ORF report section 5.1)

This phase of the work began with screen analyses of the ore feed, leading to circuit and equipment design modifications, investigations of rejection possibilities, initial quality determination and flowsheet development work to arrive at an optimized fibre extraction method. The fibre extraction concept is shown in the ORF report (Appendix A figure 4 and figure 13) and these figures are reproduced on the following pages as figure 5.2 and 5.3.

This grinding and fibre extraction concept was used in subsequent pilot plant runs, in conjunction with the grinding unit selected.

FIGURE 5-2

FIBRE EXTRACTION CIRCUIT

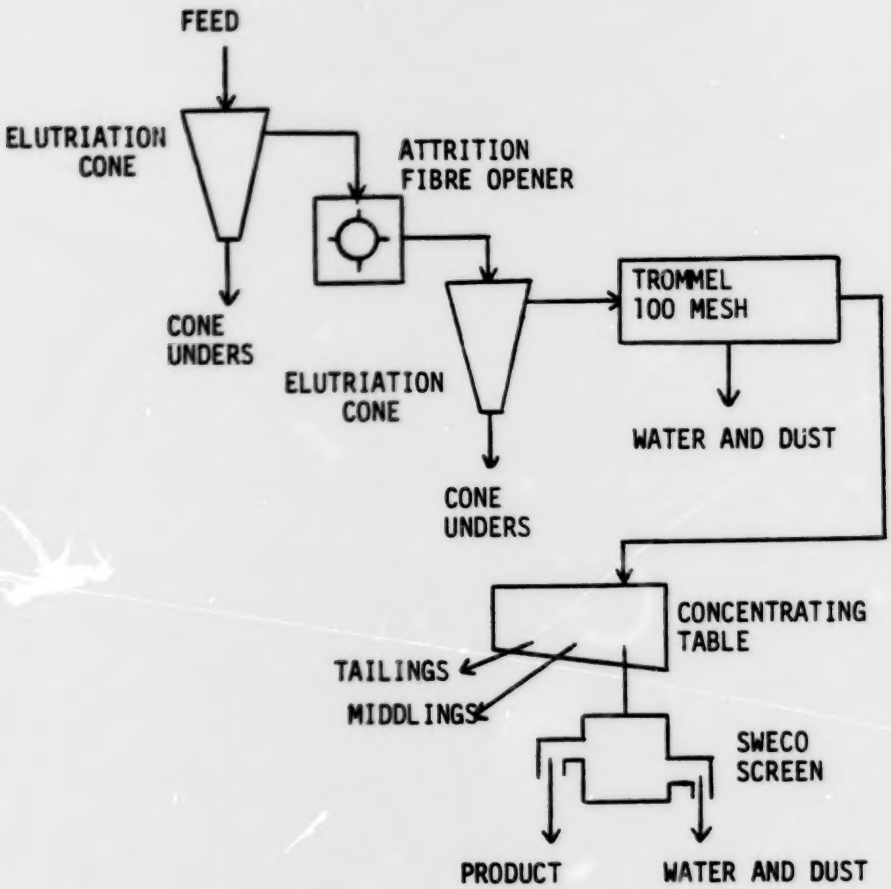
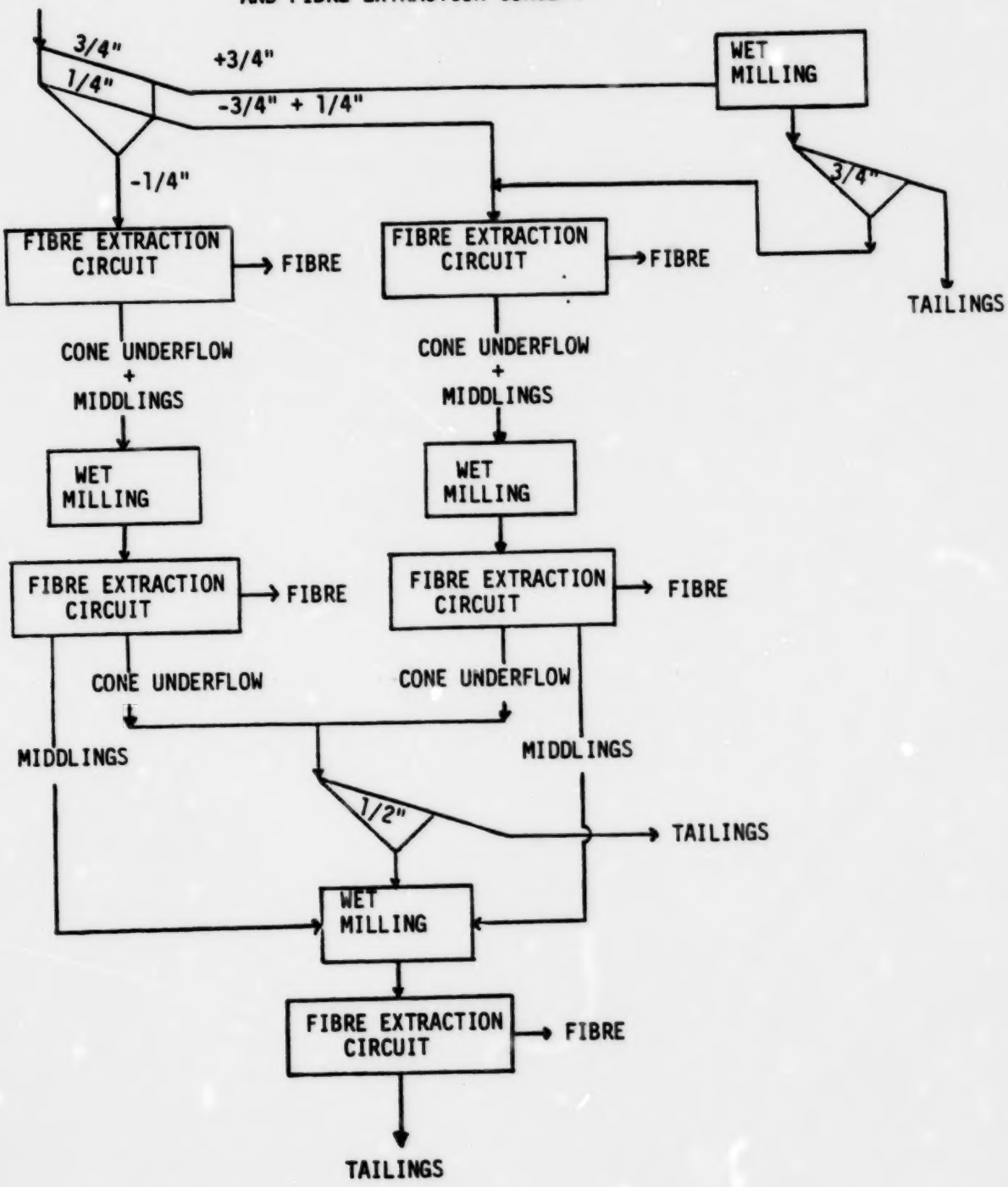


FIGURE 5-3

MULTI-STAGE GRINDING
AND FIBRE EXTRACTION CONCEPT



5.3 PRELIMINARY GRINDING STUDIES (ORF report section 5.2)

Grinding tests conducted in a Hardinge ball mill to determine the optimum grinding time based on fibre recovery, indicated an optimum retention time of five (5) minutes or less and a low pulp density (see table 5.5).

Further testing of ball charges versus rod charges with four (4) minutes retention time was carried out, indicating higher recoveries for rod milling. This is shown in table 5.6.

TABLE 5-5

HARDINGE BALL MILL GRINDING TESTS

Feed Size	Mill Conditions		Carmet Fibre Assay (WT%)					Fibre Quality						
	Grinding Time (min.)	% Solids Feed	Decanted Heavies	Trommel Unders	Concentrating Table			Surface Area (cm^2/g)	Bauer-McNett (WT%)					
					Tailings	Middlings	Concentrate (Recovery)		+4	+14	Acc +14	+35	+200	-200
+4 mesh	5	60	83.8	8.7	5.0	0.2	2.0	12,000	14	16	30	18	34	18
	10	60	66.3	17.6	10.0	3.8	2.3	--	--	--	--	--	--	--
	15	60	52.0	28.0	17.5	0.1	2.4	13,600	3	10	13	19	40	28
	5	60	83.7	6.3	6.3	0.6	3.1	10,700	7	11	18	13	25	44
	5	40	74.5	8.4	13.4	1.3	2.4	8,500	10	14	24	15	29	32
	5	30	80.6	6.7	8.4	1.5	2.8	5,900	8	9	17	10	22	51
-4 mesh	5	60	56.3	11.8	26.3	0.6	5.0	5,800	5	11	16	19	32	33
	10	60	23.6	21.0	42.3	5.0	8.1	6,800	8	13	21	17	32	30
	20	60	0	--	--	--	--	--	--	--	--	--	--	--

From Appendix A

TABLE 5-6

PRELIMINARY GRINDING TESTS - STANDARD MILL

Mill Type/ Charge	Charge: Feed	% Solids Feed	Grinding Time	Bench Scale Fibre Assay Rock	Fibre	-100 Mesh
Ball Charge: 1 1/2" balls**	20:1	20	4	92.9	3.5	3.6
Ball charge: 1 1/2" balls	10:1	30	4	96.0	2.3	1.7
Rod charge: 10 @ 2"ϕ x 11"***	20:1	20	4	91.2	3.9	4.9
Rod charge: 9 @ 2"ϕ x 11"	10:1	30	4	94.2	4.0	1.8
Rod charge: 2 @ 2 1/2"ϕ x 11"** 1 @ 2"ϕ x 11"	10:1	20*	4	97.3	1.4	1.3

* Rod charge was insufficient for proper grinding
** The 20:1 charge to feed ratio in the 20% solids mill feeds were required to allow for the large volume of water

From Appendix A

5.4 BENCH SCALE TESTING OF FOUR GRINDING MILLS

(ORF report section 5.3)

Four grinding mills were bench tested in this part of the investigation, namely: a ball mill, a rod mill, an attrition mill and a Szego mill. Test results from the bench scale tests are shown in the following tables (5-7 to 5-9).

The ball mill quality results were similar to that of the rod mill, but the latter provided higher fibre recovery results. The rod mill was chosen over the ball mill.

The attrition mill provided fibre products of inferior quality at approximately equal fibre recovery (compared to the rod mill) or unacceptable quality at a higher fibre recovery. The attrition mill was therefore eliminated.

The Szego mill produced a higher fibre recovery than the rod mill with only a slightly inferior quality. It was therefore decided to carry out further testing through the pilot plant, to provide more information.

TABLE 5-7

MILL AND QUALITY TEST RESULTS - SAMPLE III

(Rod Milling of cone underflow)

FIBRE EXTRACTION CIRCUIT (WT%)						FIBRE QUALITY						
Elutriation Cone		Trommel	Concentrating Table			Surface Area (cm^2/g)	Bauer-McNett (WT%)					
CONE I	CONE II	Unders	Tailings	Middlings	Concentrate (Recoveries)		+4	+14	Acc +14	+35	+200	-200
86.0	0.9	5.9	4.6	0.1	2.5	5800	17	18	35	22	31	12

From Appendix A

TABLE 5-8

STANDARD GRINDING TEST CONDITIONS

Mill	Test No.	Charge	Charge/ Feed	% Solids Feed	Feed Rate lb./hr.	TOTAL Feed (lb.)	MILL RPM
Ball Mill	1	1 1/2" Balls	20:1	20	N/A	30	52
	2	1 1/2" Balls	10:1	30	N/A	40	52
Rod Mill	1	2"ϕ x 11" Rods	20:1	20	N/A	25	52
	2	2"ϕ x 11" Rods	10:1	30	N/A	40	52
Attrition Mill	1	Autogenous	N/A	30	N/A	40	560
	2	1/4 " Balls	10:1	30	N/A	10	560
Szego Mill	1	N/A	N/A	30	660	.5	600
	2	N/A	N/A	30	2,200	5	600
	3	N/A	N/A	43	1,760	10	300
	4	N/A	N/A	43	1,760	10	450
	5	N/A	N/A	43	1,760	560	450

From Appendix A

TABLE 5-9

BENCH SCALE FIBRE RECOVERY AND QUALITY

Mill	Test No.	CANMET FIBRE ASSAY					FIBRE QUALITY						
		Decanted Heavies	Trommel Unders	Concentrating Table WT% Tailings	Middlings	Concentrate (Recovery)	Surface Area (cm^2/g)	Bauer-McNett (WT%) +4	+14	Acc +14	+35	+200	-200
Ball Mill	1	88.3	9.0	1.2	0.3	1.2	6000	14	21	35	21	30	14
	2	95.8	1.4	1.4	0.2	1.2	5900	17	19	36	17	30	17
Rod Mill	1	84.0	11.2	0.7	0.9	3.2	6000	10	16	26	16	29	28
	2	92.5	5.6	0.5	0.2	1.2	7600	14	16	30	17	29	24
Attrition Mill	1	87.5	6.7	3.3	0	2.5	11,000	8	13	21	17	33	29
	2	65.0	20.9	5.1	1.0	8.0	11,700	2	4	6	7	34	53
Szego Mill	1	65.3	17.9	10.5	0.8	5.5	6000	8	11	19	11	28	42
	2	--	--	--	--	--	--	-	--	--	--	--	--
	3	88.9	3.4	5.4	0.4	1.9	7200	19	20	39	21	28	12
	4	72.5	9.0	14.8	0.4	3.3	9300	8	16	24	22	34	20
	5	68.6	18,5	9.7	0.3	2.9	8000	8	15	23	19	39	19

From Appendix A

5.5 PILOT SCALE TESTING (ORF report section 6.0)

In view of the high fibre recoveries obtained in bench scale testing of the Szego mill a large sample (560 lbs) was retained for further testing. During this testing is was revealed that fibres of inferior quality were produced at approximately equal percentage recoveries as compared to rod mill results (see table 5-9 Szego mill test No 5). The Szego mill was therefore eliminated from further consideration.

The determination of a suitable percentage of solids was tested at 36,50 and 60% solids, with the former being the best of the three on a quality basis (see table 6-2). This resulted in a 20 minute retention time in the rod mill, a condition known to be excessive but considered necessary for a continuous pilot plant test, to match other circuit equipment capacities.

Table 6-2

Rod Mill Tests

Feed Rate lb./hr	% Solids	Mill RPM	Grit Content %	Surface Area cm^2/g	Degritted Bauer-McNett WT%					
					+4	+14	Acc.+14	+35	+200	-200
87	36	40	4.3	6400	14	16	30	19	30	21
91	50	40	9.6	9300	7	15	22	19	38	21
91	60	40	2.9	10700	9	14	23	20	38	19

From Appendix A

5.6 FIBRE RECOVERY AND QUALITY COMPARISON

(ORF report section 7.0)

The recovery and fibre quality of the wet process and the dry process were tested in three laboratories namely these of the ORF, LAQ and the CEGEP of Thetford Mines. The pilot plant test on the rod mill was conducted on 1960 lbs of cone underflow and the recovery results are combined with free fibre recovery. The result of the tests are shown on table 7-2. After dust adjustment to a common 30% - 200 mesh McNett (table 7-3), the percentage recovery of the wet system was 6.9% compared to results of 5.2%, an increase in recovery of 33% which in Kilborn's experience is a conservative number. It is understood that the middlings were not recovered in this test which may account for the relatively low improvement in recovery experienced.

TABLE 7-2

FIBRE RECOVERY AND QUALITY

	ONTARIO RESEARCH			LAQ		COLLEGE	
	Free Fibre	Unliberated Fibre	Blend	Free Fibre	Unliberated Fibre	Free Fibre	Unliberated Fibre
Dry Process Surface Area (cm^2/g)	6800	5800	6400	7000	5800	5650	3350
Bauer-McNett(WT%)							
+4	14	13	13	11	10	13	10
+14	16	16	16	16	16	17	18
Acc +14	30	29	29	27	26	30	28
+35	22	25	22	21	22	22	25
+200	17	12	16	19	17	20	15
-200	31	34	33	33	35	28	33
Recovery(WT%)	-	-	-	2.7	2.8	-	-
FSU	103	82	91	104	90	114	100
MR_A	326	243	287	-	-	295	278
Wet Process Surface Area (cm^2/g)	9200	6800	8300	8900	6600	2270	2450
Bauer-McNett(WT%)							
+4	12	10	12	13	14	19	15
+14	17	18	16	21	16	20	16
Acc +14	29	28	28	34	30	39	31
+35	23	17	21	19	17	21	19
-200	32	39	32	27	38	28	34
-200	16	16	19	20	15	13	16
Recovery(WT%)	2.6	3.2	5.8	-	-	-	-
FSU	113	96	97	111	88	115	90
MR_A	281	236	246	-	-	259	269

From Appendix A

TABLE 7-3

DUST ADJUSTED FIBRE
RECOVERY AND QUALITY

	ONTARIO RESEARCH			LAQ		COLLEGE	
	Free Fibre	Unliberated Fibre	Blend	Free Fibre	Unliberated Fibre	Free Fibre	Unliberated Fibre
Dry Process Bauer-McNett(WT%)							
+4	14	14	13	11	11	13	11
+14	16	16	17	17	17	16	19
Acc +14	30	30	30	28	28	29	30
+35	23	27	23	22	24	22	26
+200	17	13	17	20	18	21	15
-200	30	30	30	30	30	30	30
Recovery(WT%)	-	-	-	2.6	2.6	-	-
Wet Process Bauer-Mcnett(WT%)							
+4	10	8	10	11	12	15	12
+14	14	15	14	18	13	16	13
Acc +14	24	23	24	29	25	31	25
+35	19	14	18	17	14	17	16
+200	27	33	28	24	31	22	28
-200	30	30	30	30	30	30	30
Recovery(WT%)	3.1	3.8	6.9	-	-	-	-

From Appendix A

5.7 POWER CONSUMPTION

Historically, asbestos processors have encountered scale-up problems. Designs are therefore normally based on experience and/or pilot plant testing with full size equipment. For instance in more recent years, the Abitibi pilot plant as well as the Greek pilot plant were constructed with full size, commercial equipment. Many instances of equipment scale-up problems have been encountered by asbestos producers, for example the scale-up of a 36" diameter deduster to a 54" diameter did not meet tonnage treatment expectations. Another example is that jaw crushers which do not meet a critical 17° angle of nip, create operating problems such as blockages.

Kilborn has reviewed the ORF power calculations in the use of relatively small pilot plant equipment and concluded that scale-up problems in fact appear to exist.

Using ORF generated granulation information, Kilborn has calculated the communition requirement of asbestos as follows:

Table 5-1 of the ORF report shows that about 80% of the feed (F) passes 5/8" (= 16,000 microns). It is estimated that the total grinding requirements of ore and spicules is that 80% of the product (P) passes 10 mesh (=1600 microns). It is Kilborn's experience that the Bond Ball Mill work index of serpentine is about 12.1. Therefore we will assume a Rod Mill work index (normally 50% higher) of 18 for this ore. When the standard calculation using the Bond's work index is used, the following Kwh requirements are calculated:

$$W = 10\ Wi\ (1/\sqrt{P} - 1/\sqrt{F})$$

$$W = 10 \times 18\ (1/\sqrt{1600} - 1/\sqrt{16\ 000})$$

$$W = 18 \times (1/40 - 1/126.5) =$$

$$18\ (.025 - .0079)$$

$$W = 18 \times .0171 = 3.08\ \text{Kwh/st} = 3.40\ \text{Kwh/tonne ore}$$

where Wi is the work index and W is the work input in kilowatt hours per short ton. This calculation is consistent with Kilborn experience to install 4 Kwh/st in new rod mill applications.

Considering power alone would lead to the selection of a 3.0 m Ø x 4.3 m long (10' Ø x 14' long) rod mill with a 600 HP motor for a conventional application. Here however special conditions must be met. First the pilot plant density was 26% solids not 80% and second, the required retention time was indicated to be 4 minutes in the initial tests and pilot scale tests used 20 minutes with a steel load of less than 20%.

Since adequate scale up data is not available the selected rod mill has been sized to provide 3 minutes retention time at 36% solids with a steel load of 17% of mill volume in an overflow mill with a slurry retention volume of 40%. The resultant mill is 3.4 m Ø x 4.9 m long (11' Ø x 16' long) and is expected to draw 515 HP at 20% steel loading and 60% critical speed. A 600 HP motor must therefore be provided.

Because hammering occurs in rod mills operating at low densities, large scale tests should be done to confirm that the light load and slow speed proposed here, are adequate to allow satisfactory operation.

There is also reason to believe that by using a smaller mill and increasing the density to relieve bolt strain and hold retention time, that power requirements in primary comminution might be reduced. Larger scale tests would be required to show the full potential of power reduction.

Summarizing the key points involved in assessing the power requirements in wet comminution are:

1. Pilot plant power consumption appeared to be about 1 Kw hr/t.

2. This value is not unreasonable considering the coarse material which was discharged from the pilot plant mill.

3. It is possible that light mill density (36 percent solids) could lead to low power consumption because at this density the slurry viscosity is much lower.

4. No full scale plant data is available so it is not possible to predict with any degree of certainty what minimum power consumption will give satisfactory and reproducible results.

5. The capital and operating cost allowances for primary grinding made in this report may be conservative.

6.0 COMPARISON OF ENERGY CONSUMPTIONS

6.1 INTRODUCTION

The earlier study for CANMET, carried out by Kilborn in October 1985, in which the total capital and operating costs were compared, related to the dry and wet milling of asbestos dry mill tailings. In this process no primary communition was applied.

In the present study however, the mill feed consisted of beneficiated ore and thus communition is added to the circuit. Kilborn was requested to compare the total energy consumption and its potential savings, as well as the capital and operating costs for both processes.

Figure 6.1 illustrates the scope of the comparison study in relation to wet and dry processing of beneficiated asbestos ore.

6.2 DRY PROCESSING PLANT

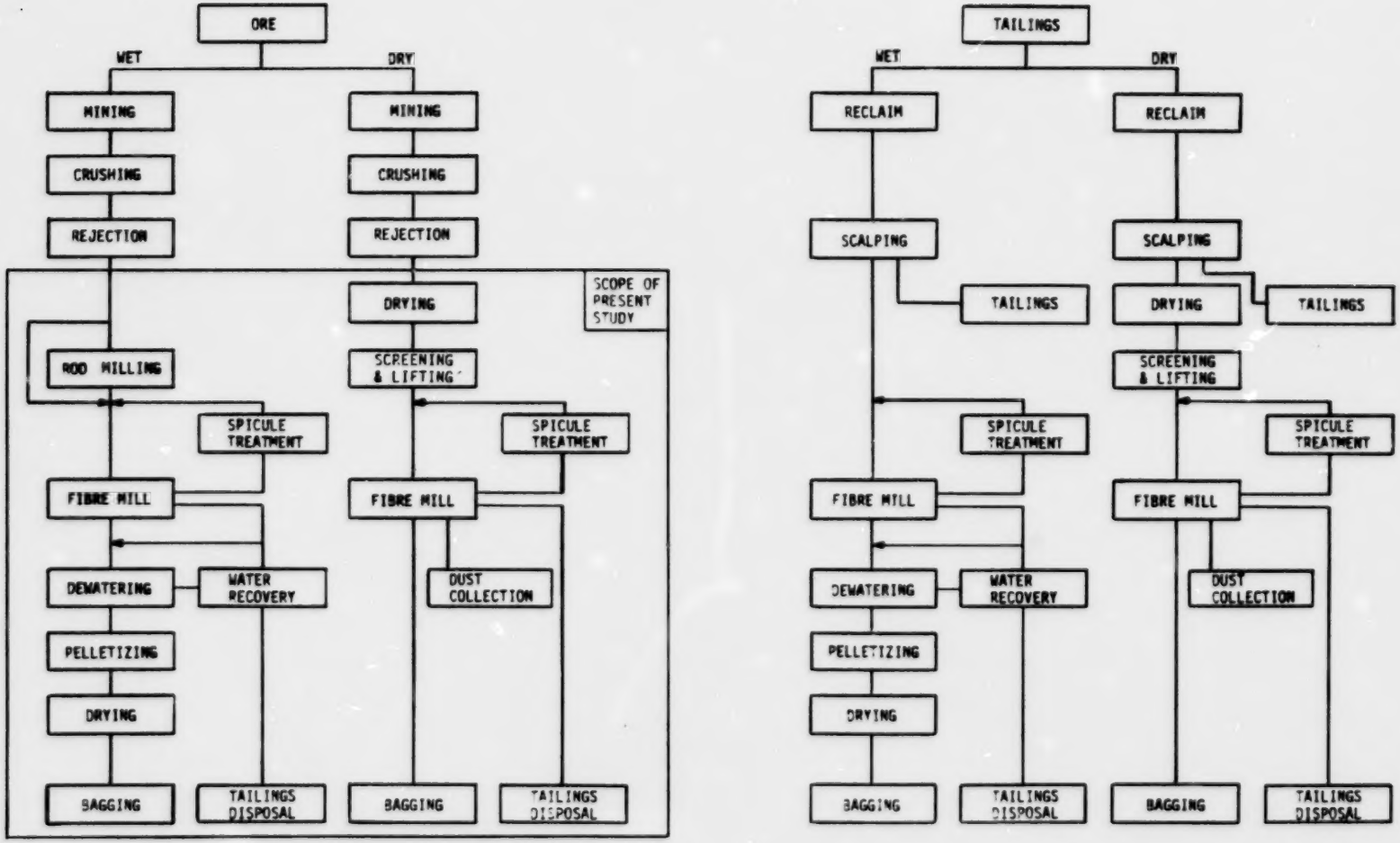
Following is a short description of the dry milling process flowsheet. The details are shown on drawing 10-F-01. The dry mill feed, which forms the basis for the concept comparison, consisted of run of the mine ore, from a mine in Thetford Mines, Quebec from which about 40-50% fibre free material has been rejected.

The beneficiated ore will be fed onto a belt conveyor which transports it to a surge bin in the dryer section of the mill. The ore is then fed, by a belt feeder, into a 2.4 m Ø x 14.2 m rotary dryer, to reduce the moisture content of the mill feed to approximately 1%. The dryer is equipped with a 40,000 cfm dust collection system.

figure 6.I

COMPARATIVE REQUIREMENTS

WET VS DRY ASBESTOS MILLING



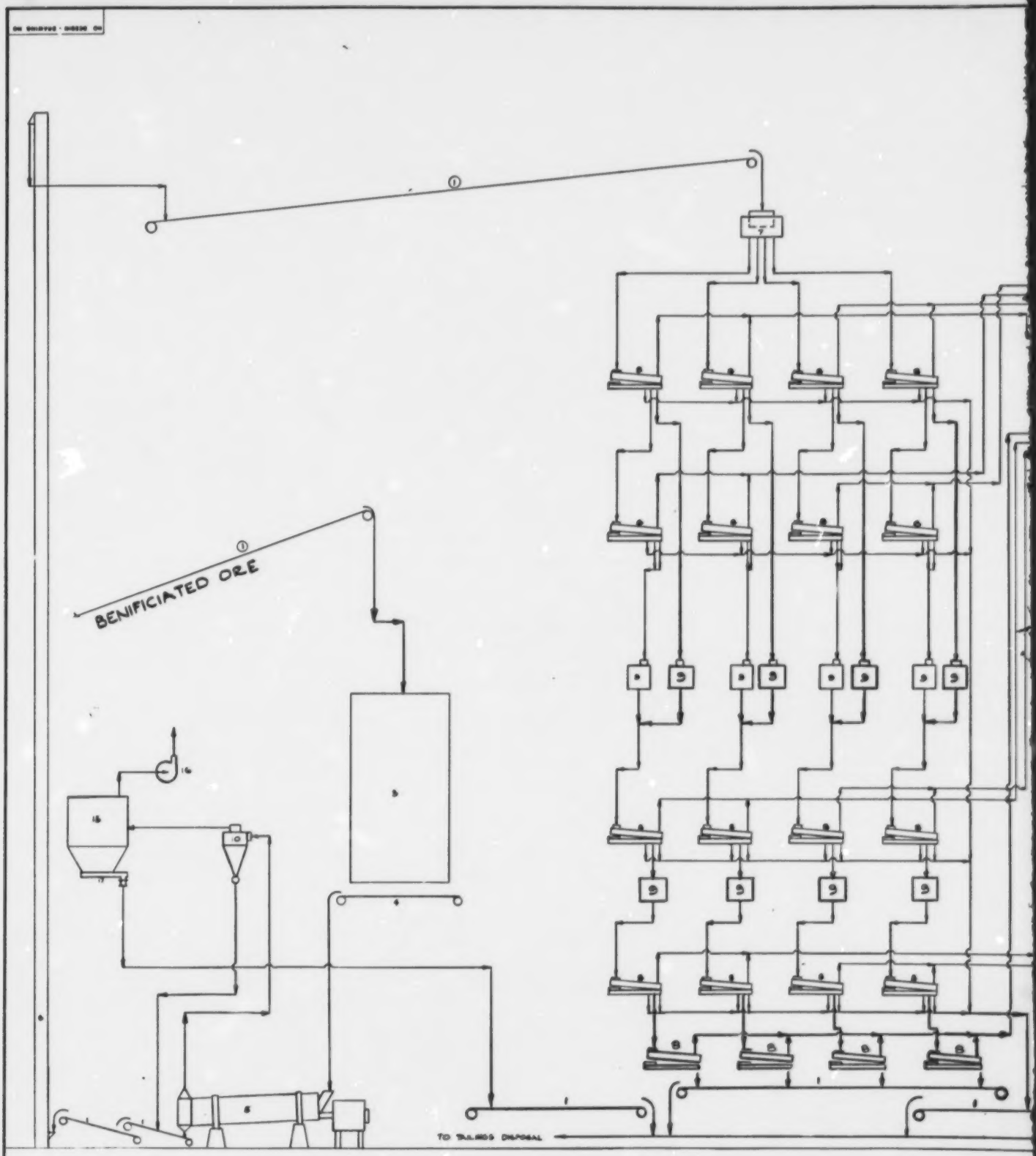
The dried product is fed by a conveyor belt system into a bucket elevator which transports the material to the main mill feed belt conveyor and into a 4-way distributor.

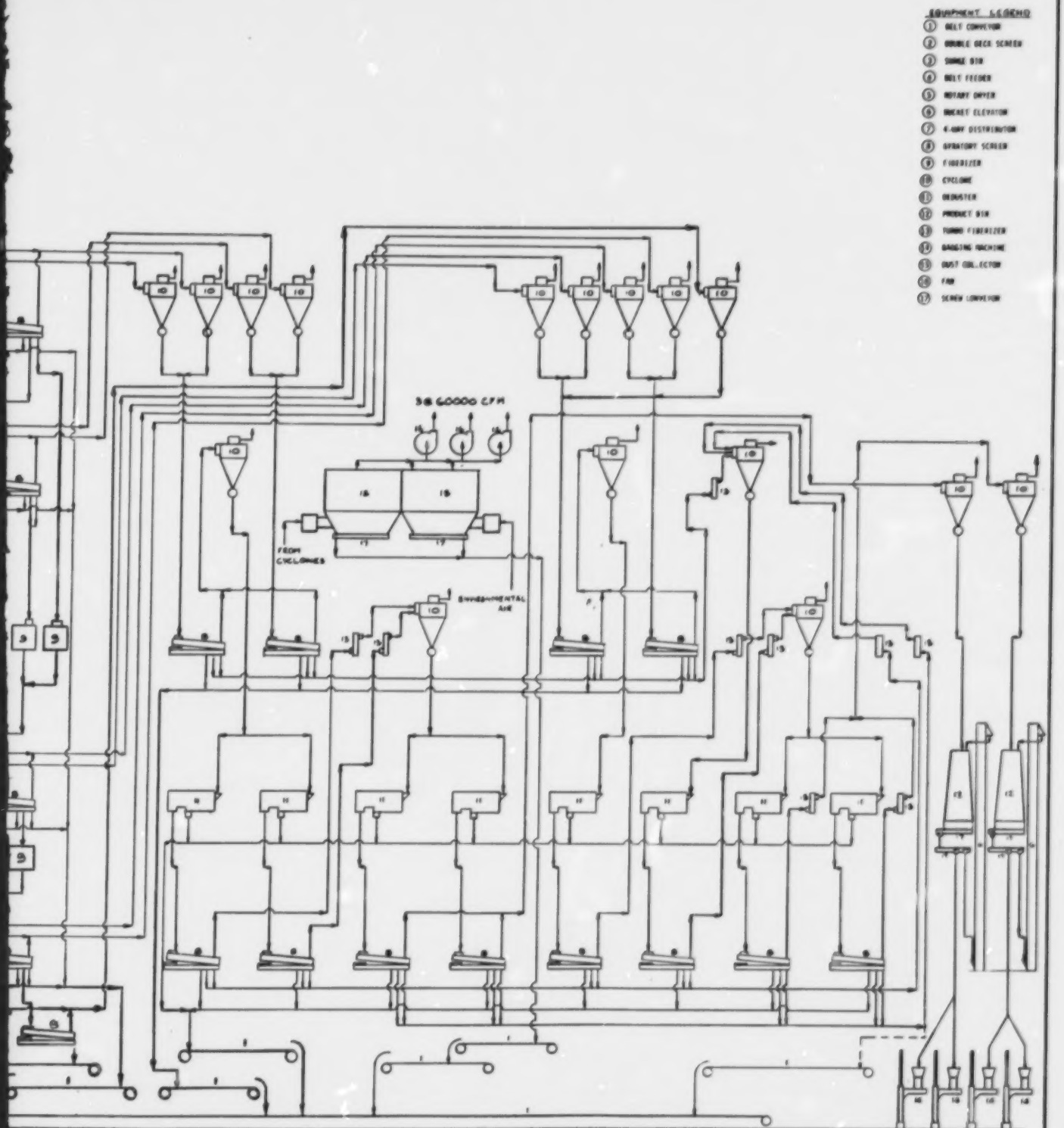
From the distributor the material is fed into four (4) double deck gyratory rockline screens where the free fibre is lifted.

The unders of these screens go to tails while the mids are screened again. The overs bypass this second screening phase and are fiberized in four (4) Torrey fiberizers. The mids and overs of the second screening stage are also fiberized, in four (4) Torrey fiberizers and combined with the fiberized overs. The material is screened over four (4) gyratory screens, equipped with a fibre lift. The unders and overs are discarded as waste while the mids will again be fiberized in four (4) Torrey fiberizers and passed over a set of four (4) rockline screens equiped with fibre lift. The unders and overs of these screens are discarded as waste while the mids are again screened on a set of four (4) rockline screens with fibre lift. All non-lifted material is then discarded as waste. The lifted fibre is collected in one set of four (4) and one set of five (5) cyclones; the first two screen lifts form the longest product (group 4) while the screens after the Torrey fiberizing, produce the shorter fibre product (group 5 and 6).

The fibre is cleaned through further screening in the fibre lines and dedusting (removal of -200 mesh) in two sets of four 0.9 m Ø x 2.4 m dedusters.

The shorter fractions of both fibre products are opened in nine (9) turbo fiberizers. The final fibre products are collected in two (2) 10 tonne capacity heavy duty, live bottom fibre bins. The fibre is then bagged through four (4) pressure packing machines.


BENIFICIATED ORE
TO TAILINGS DISPOSAL



DESCRIPTION / DATE / BY — REVISIONS	SECTION GENERAL LAYOUT	CLIENT CANMET / LAFARGE	TITLE - TITLE: 50000 TPY ASBESTOS ORE DRY PROCESS COMPOSITE FLOWSHEET	NO. JOB / PROJECT NO: 3523	NO. DRAWING / DRAWING NO: 10-F-01
	DRAWN G GOULD	LOCATION	KILBORN		

The mill is equipped with a 300,000 cfm dust collection system handling the process as well as the environmental air requirements.

6.3 WET PROCESSING PLANT

Following is a brief description of the wet process. Details are shown on the drawings 10-F-04 and 05.

It is not necessary to dry the mill feed for the wet process. The surge bin, requires ahead of the dryer in the dry milling process, is therefore not placed in the wet mill but ahead of the mill feed belt.

The beneficiated ore enters the wet mill via a conveyor belt into the primary 3.4 m Ø x 4.9 m long rod mill for grinding to about 70% - 1/4 inch. The rod mill discharge is fed onto a double deck screen from where the oversize material, amounting to 25% of the feed, is discarded as waste.

The -1/4" material is discharged into a pump box from where it is pumped into a distribution box. The slurry is agitated to complete the release of fibre. From a second series of four (4) distribution tanks the slurry is fed into thirty-two (32), four feet diameter primary cones which are arranged in sets of eight.

The cones are charged, from a point just above the narrow discharge, with possibly three jets of water which creates a circular and upward water motion. The water stream is assumed to be 4.85 m^3/hour per cone, but further test work on large scale pilot plant units must confirm the water balance throughout the described flowsheet.

The light fraction i.e. fibre, dust, spicules and fine rock, is carried to and over the top of the cone into the overflow launders. The heavier fraction is discarded from the bottom of the cone.

LEGEND

SOLIDS M.T.P.H.	WATER m³/H
% SOLIDS	SLURRY m³/H
S.G. SOLIDS	S.G. SLURRY

FROM SECONDARY CONES OVERFLOW PUMPBOX

DISTRIBUTORS

SECONDARY TROMMELS

PRIMARY CONES

PRIMARY TROMMELS

SCREW CONVEYORS

SECONDARY CONES

SCREW CONVEYORS

BENIFICIATED ORE 100 t/h

TO TAILS

TO DISTRIBUTOR

TO DISTRIBUTOR

TO DISTRIBUTOR

TO DISTRIBUTOR

SECONDARY CONES OVERFLOW PUMPBOX

TO GROUP 4 BELT FILTER FEEDS

TO GROUP 5 BELT FILTER FEEDS

TO TAILINGS SURGE TANK

TO OUTSIDE FINES BINS

DESIGNS OF REFERENCE - REFERENCE DRAWINGS

REVISIONS

GENERAL LAYOUT

G GOULD M.E.C.

CLIENT: CANFET / LAFARGE

KILBORN

TITLE: 36000 MTPY ASBESTOS ORE WET PROCESS FLOWSHEET

3825 : 15

10-F-04

FAN

DUST COLLECTOR

ROTARY VALVE

BUCKET ELEVATOR

FIBRE STORAGE BIN

SCREW CONVEYOR

SCREW CONVEYOR

BAGGER

BAGGER

FROM SURGE TANK

2.00	18.00	
10.0	18.74	
2.7	1.07	

BELT FILTER PRESS

2.00	1.08	
64.00	1.81	
2.7	1.69	

-	16.98	
-	-	
-	1.00	

EXTRUDER

DRYER

2.00	0.28	
30.0	0.74	
2.7	2.51	

GROUP 4

FROM DEWATER TABLES

1.50	4.50	
99.0	5.00	
2.7	1.17	

FROM DOUBLE DECK SCREEN

25.00	0.61	
97.60	9.87	
2.7	2.59	

FROM PRIMARY CONES UNDER FLOW

45.00	5.00	
50.00	21.67	
2.7	2.51	

FROM SECONDARY CONES UNDERFLOW

18.00	3.18	
85.00	9.84	
2.7	2.14	

SURGE BIN W/ AGITATOR

3.5	22.4	
15.5	22.7	
2.7	1.09	

BELT FILTER PRESS

3.5	1.84	
64.00	3.18	
2.7	1.69	

-	20.51	
-	-	
-	1.00	

95.00 12.57
80.51 47.76
2.7 2.29

FARMERS BELT CONVEYOR

PUMPBOX

PUMP

PUMPBOX

PUMP

-	85.89	
-	-	
-	1.00	

-	37.43	
-	-	
-	1.00	

FROM PRIMARY & SECONDARY TROMMELS

5.50	562.20	
1.00	964.24	
2.7	1.01	

MAKE UP WATER

-	8.92	
-	-	
-	1.00	

5.50	40.33	
18.00	41.97	
2.7	1.08	

THICKENER

OVERFLOW TANK

PUMP

PUMP

-	114.84	to
-	-	
-	1.00	DOUBLE DECK SCREEN

-	155.19	to
-	-	
-	1.00	PRIMARY CONES

-	172.80	to
-	-	PRIMARY
-	1.00	TROMMELS

-	43.68	to
-	-	SECONDARY
-	1.00	CONES

-	86.40	to
-	-	SECONDARY
-	1.00	TROMMELS

-	42.00	to
-	-	
-	1.00	FINES SILOS

-	6.48	
-	-	
-	1.00	

FROM SURGE BIN

3.00	27.00	
10.0	28.11	
2.7	1.07	

BELT FILTER PRESS

3.00	1.62	
64.00	2.73	
2.7	1.69	

-	35.38	
-	-	
-	1.00	

EXTRUDER

DRYER

3.00	0.33	
38.50	1.44	
2.7	2.51	

BUCKET ELEVATOR

FIBRE STORAGE BIN

SCREW CONVEYOR

SCREW CONVEYOR

BAGGER

BAGGER

GROUP 5

LEGEND

SOLIDS mt/hr	WATER m^3/hr
% SOLIDS	SLURRY m^3/hr
S.G. SOLIDS	S.G SLURRY

DESIGN

GENERAL LAYOUT

CLIENT CANMET / LAFARGE

KILBORN

TITRE - TITLE

50 000 MTPY
ASBESTOS ORE
WET PROCESS
FLOWSHEET

NO. DESSIN - DRAWING NO

10-F-05

NO. PROJET PROJECT NO. 3523

NO. DIVISION DIVISION NO. 15

The discharge of the cones is handled through a 355 mm (14") diameter, totally enclosed horizontal screw conveyor to an angled screw conveying system. The angled screw conveyor lifts the discarded material to a discharge point about three feet above the rim of the cones, in order to keep the water in the system rather than lose it with the tailings.

The overflow containing 10% solids is gravity fed into thirty-two (32) washing trommels, where -200 mesh material, is washed from the fibreous slurry with high pressure water jets. Laboratory experiments have shown that the slurry leaving the washing trommels contains about 40% solids. The discharge (underflow) of the trommels is directed to a 25 m diameter x 4 m high thickener located outside the building. From the washing trommels the reduced amount of slurry is fed into a set of sixteen (16) secondary cones for further fibre and rock separation. The discharge (underflow) of the cones is again discarded through a totally enclosed screw conveying system. The overflows of the cones, containing 10% solids, is directed to four pump boxes on the ground floor. The slurry is agitated in the pump boxes and pumped to four distributors on the top floor for subsequent discharge to sixteen (16) secondary washing trommels for further cleaning. The trommel overflow is discharged in two distribution tanks while the underflow is directed to the thickener located outside the mill.

The slurry, containing the fibre, is transported by gravity to six (6) double deck Deister gravity tables for fibre grading and final removal of spicules, grit and heavy magnetite particles. The magnetite and grit fractions are directed to the tailings filter press (described below) while the spicules are discharged into a 1.2 m Ø x 1.8 m long 50 HP rod mill for further development. The rod mill product re-enters the circuit through the pump boxes on the ground floor, for eventual recovery of the fibrous components. Grading into two fibre products is assumed to be made on the tables.

The fibre products, recovered from the Deister tables, are fed separately through two (2) pump boxes and pump(s) onto two (2) belt filter presses. The slurry entering the presses contains 10% solids and the presses will reduce the moisture content to approximately 35% moisture. The filtrate is pumped from a receiving tank to the thickener. The filter cake is directed to two (2) separate extruder-dryers, where the moisture content is further reduced to about 1%.

As mentioned before, additional drying tests are required to obtain an optimum drying technique.

The fibre pellets are transported via screw conveyors and bucket elevators into a fibre storage bin ahead of the four (4) bagging machines. A 30,000 cfm dust collection system will be installed to ensure that any free fibre, released in the drying and conveying systems, is collected.

The outside thickener receives the discharge of the washing trommels and the filtrates of the filter presses. The overflow of the thickener is discharged into an overflow tank for recirculation to the mill and the underflow is discarded to tailings. The moisture content of the underflow however, is considered too high for immediate discharge. The underflow is therefore pumped to additional filter presses (2), where the moisture content of the tailings is reduced to 35% before discharge to a tailings disposal area. It should be noted that additional test work on full scale production size equipment is required to confirm the material and water balance for detailed plant design.

6.4 CAPITAL COST ESTIMATES

6.4.1

The order of magnitude capital cost of the dry and wet processing plant treating 600,000 metric tonnes of beneficiated ore per year, recovering 5% (30,000 metric tonnes) of fibre out of the mill feed are estimated as follows:

Dry mill	$20.5 million
Wet mill	$15.8 million

The estimate is based on beneficiated ore being the mill feed. The impact crushing stages necessary for a dry mill are included, however, the equipment required for tailings disposal is excluded. The equipment installation cost is based on a labour cost estimated to be applicable for a location in Quebec. The equipment cost is based on recent budget quotations where applicable or on updated Kilborn estimates for some of the scaled-up equipment for the wet mill process plant.

6.4.2 DRY MILL CAPITAL COST

The order of magnitude capital cost estimate for the dry milling plant is based on the flowsheet and conceptual layout drawings shown in Appendix B. The details of the capital cost calculation are also attached in Appendix B. Dry milling plants are generally high structures, due to the fact that transport of fibre containing rock is done by gravity. Unneccessary rehandling of this material results in additional opening of fibre and dust impregnation which should be avoided. The conceptual design calls for a nine storey high building with a total height of 53 meters. The conveyor belt feeding the plant is included in the estimate while the equipment mining and transporting the ore are excluded. All the structures such as mill building and dryer building and the equipment within these structures are included. The bag handling system and tailings disposal system would be identical for both plants and is for this reason excluded.

Table 6-1 is a summary of the order of magnitude capital cost estimate:

TABLE 6-1
CAPITAL COST - DRY MILL

Description	Cost
Site Work	$ 46,500
Building & Structures	5,845,600
Building Services	350,000
Mechanical Equipment, including ducting	9,240,600
Process Piping for dryer	30,000
Electrical	600,000
Instrumentation	100,000
Total Direct Cost	$16,212,700
Engineering + Indirect Cost 15%	2,431,900
Contingencies 10%	1,864,500
TOTAL COST	$20,509,100

6.4.3 WET MILL CAPITAL COST

The order of magnitude capital cost estimate for the wet milling plant is based on the flowsheets and conceptual layout drawings shown in Appendix B. The details of the capital cost calculation are also attached in Appendix B.

The dry milling technique to use gravity as much as possible is also applied in the design of the wet mill where one lifting stage only is used for the feed from the rodmill and one additional lift after the secondary cones. The height, and thus the cost, of the wet mill building could probably be reduced if standard wet process techniques, such as slurry transfer through pumping, were implemented. Due to the fact that no drying is required prior to processing, a surge bin is installed before the main mill feed belt conveyor. The capital cost estimate includes this bin and belt feeder as well as the mill feed conveyor.

The mill building is five floors high for a total of 34 meters. All equipment in the building, with the exception of the bag handling system, is included in the estimate. The tailings belt, transporting the wet tailings to a tailings dump is excluded because the site for tailings disposal would be the same in both cases. The cost is therefore considered equivalent to that of the dry disposal system. However, due to the fact that more moisture is discharged with the wet system, an additional $250 000 is included for a retaining dam and pumps. Furthermore, the normal contingency of 10% is increased to 25% for the wet process plant, to reflect the more conceptual nature of the design.

Table 6-2 is a summary of the order of magnitude capital cost estimate:

TABLE 6-2
CAPITAL COST - WET MILL

Description	Cost
Site Work	$ 28,500
Building & Structures	2,762,300
Building Services	210,000
Mechanical Equipment	6,088,200
Process Piping	973,800
Electrical	569,000
Instrumentation	142,300
Tailings Disposal	250,000
Total Direct Cost	$11,024,100
Engineering + Indirect Cost 15%	1,653,600
Contingencies 25%	3,169,400
TOTAL COST	$15,847,100

6.5 OPERATING COST ESTIMATES

6.5.1 SUMMARY OF ANNUAL OPERATING COSTS

The annual operating costs can be divided into the costs which are common to both methods and the other operating costs which vary with the milling method.

The summary of the total estimated annual operating costs is shown in table 6-3.

TABLE 6-3
SUMMARY OF ANNUAL OPERATING COSTS

	DRY MILL		WET MILL	
	Total	Per t Fibre (30,300 t/y)*	Total	Per t Fibre (30,300 t/y)*
Direct overhead	600,000	19.80	600,000	19.80
Laboratory costs	260,000	8.58	260,000	8.58
Tailings disposal	300,000	9.90	300,000	9.90
General administration	925,000	30.53	925,000	30.53
Marketing	315,000	10.40	315,000	10.40
Bagging	364,000	12.00	364,000	12.00
Mill labour	2,275,000	75.08	1,575,000	51.98
Maintenance labour	945,000	31.19	840,000	27.72
Maintenance supplies	462,000	15.25	315,700	10.42
Power	425,000	14.03	319,000	10.53
Drying	642,000	21.19	420,000	13,86
TOTAL	7,513,000	247.95	6,233,700	205.72

* Tonnage reflects moisture content of 1% but excludes mining and beneficiation cost.

6.5.2 OPERATING COSTS COMMON TO BOTH METHODS

Direct Overhead

The direct overhead consist of supervisory staff safety personnel, first aid, security, etc. and the total annual cost has been estimated at $ 600,000

Laboratory Costs

The annual cost for the fibre laboratory has been estimated at $ 260,000

Tailings Disposal Cost

The annual cost of tailings disposal is based on the discharge of tailings by conveyor belt for both processes. The annual cost is estimated at $ 300,000

General Administration

The total annual cost of administrative personnel and communications, accounting, etc. is estimated at $ 925,000

Marketing Cost

The total annual cost has been estimated at $ 315,000

Bagging cost

The bagging cost includes the cost of bags, printing, pallets and wrapping and is estimated at $12.00 per metric tonne of fibre produced. The dry and wet mill will recover 30,000 metric tonnes of fibre with a moisture content of 1% for a total of 30,300 metric tonnes of fibre.

Total annual cost is 30,300 x $12 = $ 364,000

6.5.3 OTHER DRY MILL OPERATING COSTS

Labour costs

For this comparative estimate it has been assumed that the dry mill labour force would consist of sixty-five (65) hourly labourers each earning an average annual salary, including benefits, of $35,000/year.

Total annual cost $2,275,000.

The maintenance labour is estimated to consist of twenty-seven (27) hourly labourers each earning $35,000/year.

Total annual cost $945,000.

Maintenance supplies

The maintenance supplies are calculated as 5% of the mechanical equipment installed in the dry mill.

Total annual cost $462,000

Power cost

Table 6-4 shows the connected horsepower and the power cost calculation for the dry mill.

TABLE 6-4
CONNECTED HP DRY MILL

	Per Unit	No. of Units	Total
Belt Conveyor	10	1	10
Belt Feeder	10	1	10
Rotary Dryer	150	1	150
Distributor	3	1	3
Screens	5	32	160
Torrey Fiberizer	50	12	600
Airlocks	3	17	51
Dedusters	10	8	80
Turbo Fiberizers	40	9	360
Bagging Bin Screws	3	2	6
Packing Machines	75	4	300
Conveyor Belts	5	12	60
Bucket Elevators	15	3	45
Screw Conveyors	5	6	30
Dust Collector Fans	250	3	750
Dust Collector Screws	5	2	10
Dust Collector Airlock	3	1	3
Tailings Belt	10	1	10
TOTAL			2,638

Power Consumption = Total Connected HP
x Power Factor (.9)
x Kw Factor (.746)
x Hours per Year (6000)
x Price Per Kwh ($0.04) $425,077/year
say $425,000

Power Distribution Dry Milling

Using table 6.4 the power distribution is as follows:

	HP	F=.6914* Kwh	** Kwh/tonne
Drying	150	100.7	20.1
Comminution	600	402.8	80.6
Comminution Auxiliary	160	107.4	21.5
Milling Indirect	978	656.6	131.3
Aspiration	750	503.6	100.7
Total Dry Processing	2,638	1,171.1	354.2

* Hp x Powerfactor (.9) x Kw factor (.746) = Kwh

** Based on 5 tph

Drying cost

Drying cost is based on rotary dryer cost from LAQ, where the drying energy is provided by Bunker "C" oil (heating value 0.041×10^6 BTU/litre). When it is assumed that the average moisture content of the dryer feed is 6% and that of the dryer output is 1%, the required average annual energy was 2.854×10^6 BTU/t H_2O.

The following calculation determines the annual drying requirements for the dry milling operations:

Dry mill feed contains 6% moisture
All moisture in the fines (75%) which go into dryer
Dryer will bring moisture down to 1%

600,000 mt @ 6% moisture = 38,298 t H_2O
450,000 mt @ 1% moisture = 4,545 t H_2O

Removal = 33,747 t H_2O

$33,747 \times 2.854 \times 10^6$ BTU = 9.63×10^{10} BTU/year

When heating oil (energy value 30,000 BTU/litre and costing $0.20/litre) is used for drying the annual cost is:

$$\frac{9.63 \times 10^{10}}{30,000} \times \$0.20 = \$642,000$$

Kwh conversion for comparison purposes

$$\frac{9.63 \times 10^{10}}{3,413 \text{ BTU/Kw} \times 30,000 \text{ tpy}} = 940.5 \text{ Kwh/tonne}$$

6.5.4 OTHER WET MILL OPERATING COSTS

Labour costs

The labour force of the wet mill is smaller because less floor space and less equipment has to be controlled. The force is assumed to have 20 men less, namely:

- 18 floor men (wet mill has five (5) floors against nine (9) floors in dry mill)
- 2 cleaners.

Total annual cost (65-20) x $35,000 = $1,575,000

Maintenance labour force is also smaller and the standard dry milling crew is reduced by four (4) men:

3 screen repair men
1 carpenter

Annual maintenance labour cost (27-4) x $35,000 = $840,000

Maintenance supplies

Annual cost for maintenance supplies is estimated at 5% of mechanical equipment installed in the wet mill:

Total annual cost $315,700

Power cost

Table 6-5 shows the connected horsepower and the power cost calculations for the wet mill. It should be noted that although the drying energy is assumed to be supplied by steam from an electric boiler, the drying cost has been separately calculated on the basis of the use of heating oil.

TABLE 6-5

INSTALLED HP WET MILL

	Per Unit	No. of Units	Total
Belt Conveyor	5	1	5
Belt Feeder	10	1	10
Mill Feed Conveyor	10	1	10
Rod Mill	600	1	600
Screen	5	1	5
Pumps (1 spare)	100	1 (excl.spare)	100
Agitators	5	10	50
Discharge Screws (horizontal)	5	8	40
Discharge Screws (+30°)	7.5	8	60
Washing Trommels	5	48	240
Pumps (2 spares)	3	6(excl. spare)	18
Pumps (3 spares)	10	3(excl. spare)	30
Pumps (1 spare)	15	1(excl. spare)	15
Pumps (1 spare)	75	1(excl. spare)	75
Deister Tables	3	6	18
Rod Mill (spicule opening)	50	1	50
Belt Filter Press	30	4	120
Thickener	7.5	1	7.5
Extruder	100	2	200
Dryer	75	2	150
Steam Boiler*	4200	1	4200*
Screw Conveyors	5	4	20
Bucket Elevators	15	2	30
Bagging Bins Screws	3	2	6
Packing Machines	5	4	20
Dust Collector Fans	25	3	75
Dust Collector Screws	5	2	10
Dust Collector Airlock	3	1	3
Tailings Belt	10	1	10
			1,977.5

Annual cost is 1,977.5 x .9 x .746 x 6000 x $0.04 = $318,646

say, $319,000

* Drying cost calculated separately (excluded in addition of total HP).

Power Distribution Wet Milling

Based on table 6.5, the power distribution is as follows:

	HP	F=.6714* Kwh	** Kwh/tonne
Drying	150	100.7	20.1
Comminution	600	402.8	80.6
Comminution Auxiliary	5	3.4	0.7
Milling Indirect	1,134.5	761.7	152.3
Dust Control	88	59.1	11.8
Total Dry Processing	1,977.5	1,327.7	265.5

* HP x Powerfactor (.9) x Kw factor (.746) = Kwh

** Based on 5 tph

Drying cost

Data supplied for Johnson's wet milling operations showed that drying of wet asbestos from 40% to 1% moisture required 5.104 x 10^6 BTU/mt H_2O. Drying was done in an eight hearth Nichols Herreshoff dryer. The operation was considered inefficient. More efficient dryers are now available and it is assumed that the wet fibre could be dried using a total BTU which would be the average of the Johnson's wet mill and LAQ's dry mill.

$$\frac{5.104 + 2.854}{2} \times 10^6 = 3.979 \times 10^6 \text{ BTU/t } H_2O$$

The annual cost is calculated as follows:

Dryer feed from filter press is 30,000 tonnes at 35% moisture
Dryer product at 1% moisture.

30,000 @ 35% moisture = 16,154 t H_2O

30,000 @ 1% moisture = 333 t H_2O

Removal = 15,821 t H_2O

15,821 t x 3.979 x 10^6 BTU = 6.30 x 10^{10} BTU/year

In order to compare with the dry milling operation the annual drying cost has been calculated assuming that the same heating oil (energy value 30,000 BTU/litre and costing $0.20/litre) is used:

$$\frac{6.30 \times 10^{10}}{30,000} \times \$0.20 = \$419,678$$

say $420,000

Kwh conversion for comparison purposes

$$\frac{6.30 \times 10^{10}}{3,413 \text{ BTU/Kw} \times 30,000 \text{ tpy}} = 615.3$$

6.6 COMPARISONS

To arrive at true comparisons of energy consumption between dry and wet milling, Kilborn has in the first instance to reconcile the finding of a report, "The Asbestos Industry, of Phase I, Plant Studies", with Lac d'Amiante du Québec Ltée as the cooperating company. LAQ is an operating asbestos processing complex renowned for its efficiency of operation and highly optimized milling methods. Findings from this report are summerized in table 6.6.

TABLE 6.6

FIBRE PRODUCTION

AVERAGE CUMULATIVE POWER CONSUMPTION

(From the Asbestos Industry - Phase I Plant Studies)

(Table 19, page 32)

(Based on 5.53% fiber content in the dry ore)

MILL CIRCUIT	TOTAL CONSUMPTION	AUXILIARIES		COMMINUTION	
	Kwh/ tonne	Kwh/ tonne	% Total Consumption	Kwh/ tonne	% Total Consumption
Crushing	17.2	4.5	2	12.7	6
Drying	40.1	21.7	10	18.4	8
Milling	64.1	9.1	4	55.0	25
Aspiration	101.2	101.2	45	-	-
TOTAL	222.6	136.5	61	86.1	39

In order to obtain the total energy consumption various other places of energy consumption have to be considered, namely drying energy (fuel) and fibre milling energy (milling indirects).

Kilborn has completed the conceptual design of two 30,000 tpy processing plants, one dry and one wet, to enable a viable comparison of all energy components, plus capital and operating costs, leading to a cost per tonne savings of wet milling over dry milling.

The LAQ information, completed with fuel energy requirements and the milling indirects, is used as a check against overall design, whereas the dry mill for 30,000 tonnes of fibre/year, an approximately break-even design under todays marketing conditions, is used for the energy and cost comparisons with an equivalent size wet mill.

The ORF pilot plant generated information was used to complete the Kilborn designs by supplying granulation to arrive at "grinding" horsepower, quality and recovery results required for decision making for wet milling and a measure of reconciliation in the energy consumption results derived from the study.

With regards to the energy requirement for drying, the BTU requirement was directly converted to Kwh (3,413 BTU/Kwh).

Finally, in order to arrive at unit costs, capital costs were converted to yearly amortization costs and thereby unit cost per tonne, using a basis of 10% interest over 10 years. The information has been summarized in tables 6-7.A and 6-7.B.

TABLE 6.7.A
ENERGY CONSUMPTION IN Kwh/TONNE FIBRE

Location	LAQ Complex 160,000 tpy				Dry Mill 30,000 tpy				Wet Mill 30,000 tpy			
Power Consumed	Comm.	Aux/Ind	Total	%	Comm.	Aux/Ind	Total	%	Comm.	Aux/Ind	Total	%
Crushing	12.7	4.5	17.2	1.3	12.7	4.5	17.2	1.3	12.7	4.5	17.2	1.9
Drying - Elec. Power	-	21.7	21.7	1.7	-	20.1	20.1	1.5	-	20.1	20.1	2.2
- Fuel	-	940.5	940.5	72.7	-	940.5	940.5	71.7	-	615.3	615.3	68.5
Milling & Aux.	18.4	9.1	82.5	6.4	80.6	21.5	102.1	7.8	80.6	0.7	81.3	9.1
	55.0											
Milling Indirect	-	130.9	130.9	10.1	-	131.3	131.3	10.0	-	152.3	152.3	17.0
Aspiration/Dust Control	-	101.2	101.2	7.8	-	100.7	100.7	7.7	-	11.8	11.8	1.3
Totals	86.1	1 207.9	1 294.0	100.0	93.3	1 218.6	1 311.9	100.0	93.3	804.7	898.0	100.0
Kwh Savings/tonne			N.A.	N.A.			Base	Base			413.9	31.5

TABLE 6.7.B
YEARLY AMORTIZATION* AND OPERATING COSTS $/TONNE

	Dry Mill	Wet Mill	Savings	% Cost	% Savings
Energy - Elec. at 4¢/Kw	14.03	10.53	3.50	1.0	5.2
- Fuel at 20¢/l	21.19	13.86	7.33	2.0	10.9
Capital Costs	110.13	85.09	25.04	7.0	37.2
Operating Costs	212.73	181.33	31.40	8.8	46.7
Total	358.08	290.81	67.27	18.8	100.0

*Based on 10% interest/10 years Factor .1627

7.0 CONCLUSIONS AND RECOMMENDATIONS

On the basis of the foregoing, Kilborn concludes the following:

- The comparison of communition Kwh/tonne (93.3 versus 93.3) shows that no substantial Kwh savings can be expected directly from comminution of asbestos in wet milling.
- The comparison of total power consumption, excluding drying fuel energy, shows that a modest saving is found in power consumption of the total wet mill installation of approximately 89 Kwh/tonne.
- Substantial energy savings are found in the drying energy required for wet milling, approximately 326 Kwh/tonne.
- Substantial savings in capital and operating costs are also registered.

In economic terms, the savings of wet milling over dry milling are as follows:

- Power savings	$ 3.50/tonne of fibre
- Fuel savings	$ 7.33/tonne of fibre
- Capital Cost savings	$ 25.04/tonne of fibre
- Operating Costs	$ 31.40/tonne of fibre
Total savings	$ 67.27/tonne of fibre

The above indicates an important competitive edge for wet milling over dry milling, although some aspects need further investigation. Following the indicated potential savings Kilborn recommends:

- that the drying aspect of wet milling be further investigated due to its interesting potential in terms of energy conservation.

- that larger scale grinding tests on asbestos ore be done prior to implementation of a wet flowsheet on a commercial scale in order to optimize energy consumption and to confirm the scale up assumptions made in this report.

- that further testing of any wet milling equipment should be done on full size commercial equipment, to alleviate scale-up problems which are common to this industry.

- that additional work is carried out on filter pressing of asbestos slurries, which is not yet a completely resolved design aspect.

APPENDIX A

Comminution - Phase III
Activity No. 5

WET COMMINUTION OF ASBESTOS

CANMET CONTRACT NO. 20018

Kilborn Ltd

RESEARCH

Comminution - Phase III
Activity No. 5

WET COMMINUTION OF ASBESTOS

CANMET CONTRACT NO. 20018

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Final Report #64-10510

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SUMMARY

Under the direction of CANMET, a study was commissioned to look at the energy requirements for industrial mineral comminution. This task of the study involved the wet comminution of asbestos. The task was completed in two phases. The first phase involved a bench scale study designed to test and choose the best mill to grind asbestos ore in a wet medium. The second phase of the study was to conduct pilot scale wet asbestos grinding. Fibre recovery, quality, capacity and energy requirements of the wet circuit was determined and was compared, where possible, to products from the dry process of Lac de l'Amiante du Quebec, Ltee, in Black Lake, Quebec.

The first phase of the study investigated the merits of the rod mill, ball mill, attrition mill and the Szego mill. Batch tests indicated that the rod mill produced the best quality fibre in relation to fibre recovery. Both the attrition and Szego mills liberated more fibre, but tended to give an inferior product. The rod mill was chosen for the pilot scale test.

The pilot scale test work provided the recovery and quality determinations that were used in the wet and dry circuit comparisons. The study resulted in the following conclusions:

The wet mill provided a greater fibre recovery than the dry mill. The wet processed fibre was slightly shorter, less dusty (less -200 mesh content) and stronger, by the FSU Strength Unit.

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1. INTRODUCTION

Canada Cement Lafarge, was given a mandate by Canmet with funding from the energy sector to conduct grinding studies on specified industrial minerals. Ontario Research Foundation and Kilborn Engineering were awarded the task of determining an optimum energy efficient method for wet comminution of asbestos ore, while maintaining fibre quality.

Previous work at Ontario Research with wet asbestos processes provided a method of free fibre extraction from the ore. Some modification to the circuit was done to reflect the nature of the ore feed material. Comminution studies were done on mill feed ore supplied by Lac d'Amiante du Quebec, Ltee (LAQ), Black Lake, Quebec.

The project was divided into two phases: bench scale and pilot plant scale. Test work and results will be reported somewhat chronologically.

2. MATERIAL SAMPLING

The samples of asbestos ore (a one short ton head sample and a 10 short ton bulk sample) were collected from the main mill feed belt at the processing plant of LAQ Asbestos. Figure 1 shows the primary crushing circuit and Figure 2 shows the drying and beneficiation circuit used to provide these samples. These figures are presented in Appendix A, following this report.

Initial mine feed material was jaw and cone crushed in closed circuit with coarse screening to provide -5 1/2" material for wet rock storage. This material was further classified, reduced, and concentrated by impaction, screening and magnetic separation. It was passed through a dryer and put into dry rock storage. The dry rock storage provided the feed material for the mill, which was sampled for the wet asbestos processing program.

2.1 Mill and Test Sampling

In a comparison study of this nature, it is important that proper sampling procedures are followed. Any sample that has a wide particle size distribution tends to segregate. This is especially true with asbestos ore, which tends to segregate automatically with fine particles and fibre tending to migrate to the bottom of a sample, and coarse material tending to "float" to the top of a sample. The mill feed enters the plant by belt conveyor. A continuous sampling of the belt with a splitter of some sort was not considered proper because of this segregation. The belt was therefore stopped and the entire length was sampled.

Any subsequent sampling at Ontario Research was done as representatively as possible. An initial two ton head sample was blended on the pilot plant floor using a front end loader. With the exception of two grab samples, all tests using the head sample were performed on representative samples that were coned and quartered. For smaller samples, the material was further reduced using a riffle sampling method.

The 10 ton mill feed sample was not blended at Ontario Research. Where comparative tests were required, representative samples were taken from the same barrel. The full scale pilot plant tests used samples as large as possible in order to reduce the possibility of non-homogeneous sampling of the ore; which would affect the results.

3. DRY FIBRE EXTRACTION METHODS AND RESULTS

In order to determine any energy savings in wet grinding and extraction over conventional dry processing, a portion of the mill feed was processed through a dry circuit. The asbestos producer owns a core milling circuit which is regularly used to determine the quality of mill feed, the efficiency of their mill, and the variation of their ore. This core mill circuit was used in the program to provide an estimate of

product quantity, quality, throughput and energy consumption on the mill feed sample chosen for this study. A correlation exists between the Producer's core mill and their production mill.

The core mill provides an initial free fibre lift using two inclined vibrating screens containing 26 and 40 mesh screen cloths, with an aspirator attached to the oversize discharge of each. Unliberated fibre was recovered by three crushing stages, with intermediate screening and aspiration (see Figure 3 in Appendix A).

The two samples produced by the core mill were evaluated for length distribution using the Bauer-McNett classifier and for strength, using the Fibre Strength Unit. These tests were also conducted by LAQ Asbestos and by the College de la Region de l'Amiante in Thetford Mines. The results are shown in Table 3-1.

4. WET PROCESSING-FIBRE EXTRACTION METHODS

The general concept of asbestos fibre processing, wet or dry, is to liberate the veins of fibre locked in the ore and sufficiently open, or fiberize, the asbestos fibre so that it can be classified and separated from the gangue material. In the present wet comminution study, this separation was done by using three methods, termed the "Fibre Extraction Circuit", the "Canmet Fibre Assay", and the "Bench Scale Fibre Assay". The three methods reflect three scales of fibre recovery and are described in the following sections. These circuits are shown in Appendix A (Figures 4 and 5).

4.1 The Fibre Extraction Circuit

The fibre extraction circuit, previously developed at ORF, was the standard circuit employed to recover liberated fibre from ore (see Figure 4). This circuit was used for samples greater than 50 lbs.

TABLE 3-1

DRY MILL FIBRE RECOVERY AND QUALITY

	Ontario Research			LAC		College de la Region de l'Amiante	
	Free Fibre	Unliberated Fibre	Blend	Free Fibre	Unliberated Fibre	Free Fibre	Unliberated Fibre
Surface Area (cm^2/g)	6800	5800	6400	7000	5800	5650	3350
Bauer-McNett (WT%)							
+4	14	13	13	11	10	13	10
+14	16	16	16	16	16	17	18
Acc +14	30	29	29	27	26	30	28
+35	22	25	22	21	22	22	25
+200	17	12	16	19	17	20	15
-200	31	34	33	33	35	28	33
Recovery (WT%)	-	-	-	2.7	2.8	-	-
FSU	103	82	91	104	90	114	100
MRA	326	243	287	-	-	295	278

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A vibratory feeder was used to convey dry ore into the first elutriation cone; at the rate of 200 lb./hr. Coarse grit was separated from fine grit and fibre by apparent density difference, and was settled out as the elutriation cone underflow. The fibre and fine grit discharged as an overflow into a small attrition fibre opener; which was used to open any crudy fibre prior to further classification. The attrition fibre opener discharged into a second elutriation cone, where a similar degritting procedure to the first elutriation cone took place; removing all but the finest grit.

The overflow from the second cone was very dilute, and was fed through a trommel screener (using a 100 mesh screen cloth), where it was both washed and dewatered. The washing removed the fines from the system. Typical solids washed from the fibre was composed of 80% less than 200 mesh material. The dewatered and dedusted trommel screen overflow fibre product was processed over a concentrating table; where the fibre reported as a low gravity product, and the gangue material reported as a high gravity product. A middlings product was also recovered, consisting of fine grit, fibre and unopened spicules. The fibre, middlings and gangue were collected separately. The fibre concentrate underwent one final continuous dewatering and dedusting stage on an 18" Sweco screen, providing a product of approximately 30% solids. Further mechanical dewatering was done using a pressure filter which prepared a fibre product containing approximately 70% solids. Capacities and water/solids ratios in this circuit are discussed in section 7 of this report.

4.2 The Canmet Fibre Assay

The Canmet fibre assay was used for smaller ore samples ranging from 5 to 50 lbs. This size of a sample could not be efficiently processed through the larger fibre extraction circuit elutriation cones. The cones were replaced by a decantation method. The asbestos bearing material was diluted in water, agitated to suspend the fibre, and quickly decanted to pour off the fibre and finer grit. This was done repeatedly, until all the free fibre was removed, leaving behind the coarse grit.

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The fibre and fine grit concentrated by the decantations resembled the elutriation cone overflows of the fibre extraction circuit. This material was passed through the trommel screen and the concentrating table to produce a concentrate, middlings and tailings as in the large scale fibre extract circuit (see Figure 5).

The Canmet Fibre Assay replaced the elutriation cones with a quick decantation method, allowing smaller samples to be processed in a similar manner to the larger samples. Direct comparisons to the two processes could be made.

4.3 The Bench Scale Fibre Assay

The Bench Scale fibre assay was developed for use in small bench scale fibre extraction studies. The samples tested by this method ranges from 1 to 5 lbs and were considered to be too small for both the elutriation cones and trommel screen. With small samples, not only were the elutriation cones oversized, but the residence time in the trommel screen was much longer than required. Hang up in the system would result in losses of up to 50% for this size of sample. Normally quick estimates could not be directly compared to the other two tests.

This test used repeated decantations similar to those used for the Canmet Fibre Assay method in order to remove the fibre from the heavier gangue material until all but fibre and water remained. Fibre samples tended to be grittier and dustier than those obtained from the other tests, but they gave a quick indication of fibre quantity and quality.

4.4 Grinding Equipment Description

Four types of grinding mills were evaluated in this study, the ball, rod, attrition and Szego mills. A brief description of each follows.

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4.4.1 Ball Mill

Two types of ball mills were examined in this study. Initial testing was done on a 2 foot Hardinge conical ball mill. It operated at 95% of critical speed, with a ball load of 396 lbs. of 1 1/2" steel balls.

Standard ball mill grinding tests were conducted on a 12" diameter x 12" cylindrical mill that could be converted into a rod mill when required. It was loaded with 1 1/2" steel balls, to approximately 40% of the mill volume.

4.4.2 Rod Mill

Two types of rod mills were examined in this study. Bench scale testing was done on the 12" x 12" cylindrical mill used for the ball mill tests. It was loaded with 2" diameter and 2 1/2" diameter x 11" rods to approximately 40% of the mill volume.

A Hardinge cylindrical rod mill 2' diameter x 3', was used for the pilot scale grinding tests. It was operated at 75% critical speed with a rod charge of 577 lbs. of 2" diameter x 30" rods.

4.4.3 Attrition Mill

The attrition mill had a vertical, rubber lined cylindrical shell and a 9" x 14" central shaft with pegs operating at 840 rpm provided the attritioning action to the feed material. The attrition mill (Figure 6) was operated with grinding media (1/4" steel balls) and autogenously.

4.4.4 Szego Mill

The fourth mill was a Szego mill, manufactured by General Comminution Inc. The Szego mill uses a stationary cylindrical shell with grooved, radially mobile rollers that rotate around a central shaft. The mill has several design variables to vary the grinding process: the

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number, diameter and length of the rollers, the size, shape and pitch of the helical grooves in the rollers, the rotational speed of the rollers, and the mill feed rate. The model used in this study was designated as SM-220-1 (pilot mill); which had a capacity of 1000 kg/hr (see Figure 7).

4.5 Wet Fibre Extraction Equipment Description

4.5.1 Elutriation Cone

The elutriation cone consisted of an open top and bottom that was equipped with four water spray nozzles to generate a gentle, free vortex. The bottom discharge fed a sealed container, forcing the water flow upward to the top discharge (see Figure 8 in Appendix A). Dry ore was fed directly into the centre of the cone, where it was allowed to sink into the vortex. The coarse material tended to spiral downward and be discharged as underflow, while the finer material spiraled upwards to be discharged as overflow. The classification size of the elutriation cone could be controlled by the water flow to the spray nozzles.

The elutriation cones were operated under low pressures and water volumes, in comparison to a hydrocyclone of equal size. It classified material due to the upwelling of water, resulting from a contained lower discharge. For the purposes of this study, the container used (for the cone underflow discharge) was a sealed 45 gallon drum. This necessitated a batch process. With a feed rate to the first elutriation cone of 200 lbs. per hour, the cones could be fed for approximately 3 hours before the discharge drum had to be changed.

4.5.2 Dewatering and Dedusting Equipment

The trommel, or drum screen, consisted of a rotating tube (12" diameter x 4'). An inner 100 mesh screen cloth was used to dewater and dedust the cone overflow. The tube screen was supplied with inner and outer spray systems in order to wash the fibre and reduce screen from blinding. The spray nozzles were controlled by pressure regulators.

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The rotational speed of the tube was controlled by a variable speed motor. Rotation speed, feed rates and spray nozzle pressures of the trommel were varied to optimize the product (see Figure 9 in Appendix A).

An 18" diameter Sweco screener, using a 100 mesh screen was used to dewater and dedust the fibre concentrate from the concentrating table. The fibre concentrate was pumped to the center of the screen. Dewatering and dedusting took place as the fibre travelled to the edge of the screener and was discharged (see Figure 10).

4.5.3 Attrition Fibre Opener

In previous wet fibre extraction studies, it was noted that some mechanical fibre opening was required to better separate the fibre from the fine gangue, in the second cone and concentrating table operations. The attrition fibre opener provided this opening.

The mill container consisted of four vanes running down the sides in order to prevent vortexing. The shaft and shearing impeller ran down the centre of the container, with the impeller near the bottom of the container. The impeller itself consisted of square bars, which provided a impact and shearing action. Material was fed from the top as a thin slurry. Coarse material and unopened fibre would sink and be hit by the impeller. The material leaving the overflow was sufficiently opened for further processing (see Figure 11 presented in Appendix A).

4.5.4 Concentrating Table

A Wilfley No.13 concentrating table (2'x4') equipped with a sand deck was used for the final fibre degritting operation. When set at a low angle, the table generated three products. The fibre and dust reported to the area of the table that normally produces light material. The coarser and heavier grit travelled along the table and was separated from the fibre and dust. In most instances, unopened fibre, spicules and fine grit was collected separately as middlings product between the fibre and the fibre free tailings (see Figure 12 in Appendix A).

5. BENCH SCALE TESTING

5.1 Preliminary Testing

The test work on the LAQ asbestos mill feed material began using the two ton head sample, which was delivered in eight barrels. The head sample was blended and split for the various tests.

5.1.1 Grab Sample Screen Analysis

Two grab samples were taken of the head sample for a determination of particle size and fibre content. These were the only two samples that were not taken by sampling methods, such as cone and quartering or riffling. The two samples were sieved and a particle size distribution was determined. The individual fibre content of each sieve fraction was determined by the bench scale fibre assay method described in section 4.3. The results are listed in Table 5-1.

The screen analysis shows that 60% of the material was larger than 4 mesh, with a free fibre recovery of approximately 5%. The quality of the fibre was not tested due to insuffient sample quantity.

5.1.2 Multi-Stage Comminution

Initial discussions with the Scientific Authority indicated interest in a multi-stage grinding and fibre extraction circuit. In an attempt to produce various fibre grades, the mill feed material would be wet screened on a double deck Dillon screener. The +3/4" material (approximately 15% of the feed) would be wet milled and rescreened. The -3/4" fraction would be accepted for further processing, while the +3/4" material would be rejected. The -3/4" fraction would be combined with the original -3/4" +1/4" material reporting to the initial free fibre extraction circuit described in Section 2.1. The elutriation cone underflows and the middlings could be recombined and passed again through the wet milling and fibre extraction circuits.

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TABLE 5-1

GRAB SAMPLE ROCK AND FIBRE CONTENT

GRAB SAMPLE I				GRAB SAMPLE II			
Screen Fraction	Rock Content (WT%)	Free Fibre Content (WT%)	Unliberated Fibre Content (WT%)	Screen Fraction	Rock Content (WT%)	Free Fibre Content (WT%)	Unliberated Fibre Content (WT%)
+3/4"	12.8	0	--	+3/4"	--	--	--
+1/2" M	14.5	0	--	+1/2"	28.6	0	1.7
+4 M	32.4	0	--	+4 M	27.5	0	4.6
+10 M	20.1	3.8	--	+10 M	19.0	4.1	--
+35 M	7.1	1.3	--	+35 M	7.0	0.8	--
-35 M	8.0	0	--	-35 M	6.7	0	--
TOTAL	94.9	5.1	--	TOTAL	88.8	4.9	6.3

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The -1/4" material was passed through a similar milling and fibre extraction circuit. Four separate fibre recoveries would result; two free fibre extractions and 2 unliberated fibre extractions. The elutriation cone underflows from these two parallel flowsheets would be combined, and the -1/4" fraction and middlings products milled once again, to give a final fibre recovery. Figure 13 in Appendix A shows this discussion flowsheet.

Although a circuit of this complexity was considered beyond the scope of this study, the concept of subjecting the initial three screen fractions to different degrees of grinding was tested. The testing was done in the following manner:

1. The mill feed material was classified according to the front end of the flowsheet.

2. Free fibre extraction of the individual fractions were done using the methods described in sections 4.1 to 4.3, depending on the size of the sample.

3. Since a milling technique was not yet investigated all milling to free unliberated fibre was done dry in a Hazemag impact crusher. A wet method was used to extract the liberated fibre.

The 50 lb. sample of mill feed was wet screened on a Dillon screener to give a fibre free +3/4" fraction. This fraction was dried, passed through a laboratory Hazemag impact crusher, and evaluated for unliberated fibre content using the bench scale fibre assay method. The unliberated fibre contained in the +3/4" material was 0.15% wt of the sample. This suggested that the +3/4" fraction was relatively barren.

A large (400 lb.) sample (designated as Sample I), was wet screened into three fractions: +3/4", -3/4" + 1/4", -1/4" according to the flowsheet shown in Figure 12 of Appendix A. All free fibre reported to the -1/4 fraction. The +3/4" and the -3/4" + 1/4" fractions were dried and passed through a laboratory impact crusher. Representative samples of these impacted fractions were riffled and the unliberated fibre content was determined using the bench scale fibre assay method.

The -1/4" fraction contained the free fibre, and consequently it was processed through the fibre extraction circuit. Samples from the fibre extraction circuit Cone 1 and Middlings products (see Figure 4 in Appendix A) were dried, riffled and impacted. The amount of released fibre was assayed using the bench scale fibre assay method. The rock and fibre distribution of the three fractions are shown in Table 5-2 below.

Table 5-2

Sample I Rock and Fibre Distribution

Screen Size	Rock Wt%	Liberated Fibre Wt %	Unliberated Fibre Wt %
+ 3/4"	7.74	0	0.06
+ 1/4"	40.88	0	0.62
- 1/4"	42.74	7.1	0.86
TOTAL	91.36	7.1	1.54

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The total fibre recovered from this sample was 8.64% by weight while 91.36% of the material was considered as rock. Of the total fibre recovered, 82.1% was free fibre, while 17.9% was unliberated fibre, recovered after crushing. The +3/4" fraction contributed 0.7% of the total fibre recovery, the -3/4" +1/4" fraction contributed 7.2% of the fibre and the -1/4" fraction contributed 92.1% of the fibre.

Based on the results of the larger test run, it was decided that rather than performing grinding tests on three free fibre sized fractions of ore, the tests should be performed on two fractions of approximately equal weight. A 583 lb. sample (Sample II) of mill feed material was processed through the fibre extraction circuit in order to remove free fibre. Due to the limitation of the 2 inch bottom discharge of the elutriation cones, the mill feed material was reduced to -1/2" using a rolls crusher in order to prevent any possible blockage in the discharge pipe.

The fibre extraction circuit was performed as in previous runs, with one exception. The trommel discharge, containing fibre and grit was often not completely dispersed before it was presented to the concentrating table. This resulted in tangles of fibre travelling along the table with the grit, and consequently discharging as a heavy product. These tangles constituted 0.2% of the total weight, and were reported as table concentrate. These tangles were eliminated in later runs by dispersing the trommel discharge before it was presented to the table.

The two cone underflows from the fibre extraction circuit were screened on a 4 mesh screen cloth in order to produce two fractions of relatively equal weight. The middlings product was added to the fine fraction. These two screened "fibre free" fractions were used in the initial grinding studies.

Table 5-3 lists the mass balances of the wet milling and fibre extraction done on Sample II. As expected, elutriation cone 1 underflow fraction contained most of the material. The free fibre concentrate

comprised 2.2% Wt of the sample, which was significantly less than the free fibre contents of previous tests.

TABLE 5-3

SAMPLE II ROCK AND FIBRE DISTRIBUTION

	Fibre Extraction Circuit (WT%)					
	Elutriation Cone		Trommel Underflow	Concentrating Table		
	I	II		Tailings	Middlings	Concentrate
Rock	83.7	0.86	7.0	3.8	0.15	0
Free Fibre Content	0	0	0	0	0	2.2
Unliberated Fibre Content	2.0	0.14	0	0	0.15	0
TOTAL	85.7	1.0	7.0	3.8	0.3	2.2

The reject products from the fibre extraction circuit were evaluated for unliberated fibre content using the dry impact crusher technique described previously. The impacted cone I underflow was evaluated using the Canmet fibre assay method, while the cone II underflow and the middlings were evaluated using the bench scale fibre assay method. The rock and fibre distribution of this sample shown in Table 5-3 indicate that the sample contained approximately equal amounts of free and unliberated fibre, for a total fibre recovery of 4.5%. This was a significant change from the previous sample which contained 8.6% fibre, 82% of which was free fibre.

The fibre quality of the various fibre products from this test was compared by determining the fibre length distribution using the Bauer-McNett and the West Test, according to QAMA standards. These results are listed in Table 5-4.

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TABLE 5-4

SAMPLE II FIBRE PRODUCT QUALITY

Product	Surface Area (cm /g)	Bauer-McNett Classifier (WT%) +4	+14	Acc +14	+35	+200	-200
Free Fibre	4100	12	19	31	25	30	14
Unliberated Fibre (Cone I Underflow)	3100	28	15	43	7	6	44
Unliberated Fibre (Cone II Overflow)	3200	24	23	46	10	10	34
DEGRITTED AND OPENED FIBRE PRODUCTS							
Free Fibre	6900	9	20	29	24	38	9
Unliberated Fibre (Cone I Underflow)	6300	9	15	24	25	36	15
Unliberated Fibre (Cone II Underflow)	7400	9	17	26	26	38	10

5.1.3 Preliminary Testing Conclusions

Efforts to quantify the total fibre content and occurrence (free vs. unliberated) seemed to be somewhat inconclusive in these preliminary studies. The two grab samples and the riffled sample screen analyses indicated a free fibre content of approximately 4.8% and an unliberated fibre content of 6.3% coming from the +4 mesh fraction. This indicated that the unliberated fibre content was larger than the free fibre content in the mill feed material.

Sample I had a free fibre content of 7.1% and a unliberated fibre content of 1.5%. Sample II had a total fibre content of 4.5%; split equally between the free and unliberated mode. This indicated a significant difference in the fibre content and occurrence.

These inconsistent results suggested a sampling problem. Sampling can be a significant problem in materials with a wide range of particle sizes. Segregation tends to take place in a sample as the finer particles sift their way to the bottom of the sample. This is especially true with this ore which is rather coarse, yet has a fine grit and fibre fraction. A determination of the free fibre content of this ore would have to be determined from the larger samples, or from combining several tests.

The unliberated fibre content of the ore may also present a sampling problem. That too would be overcome with larger samples. To keep consistent feed samples for the grinding tests, the grinding tests to be done on liberated fibre free ore would be done on a single sample (eg. Sample II). Comparisons between individual tests could then be made. Grinding tests made of samples from different feed material might not be comparable.

A discrepancy seemed to have also occurred in the fibre length distributions of the various fibre products from Sample II. Table 5-4 indicated that the reground material (cone I and cone II underflows) was twice as long as the free fibre concentrate, given the same dust level. The Bauer-McNett fibre length determinations were done on the fibre delivered from the mill. Surface areas were not determined. Bauer-McNetts were done in duplicate and a wash test (-200 mesh determination) was used to confirm the Bauer-McNett results. The fibre was degritted before these tests were conducted.

A second set of Bauer-McNett tests were performed on these fibre products, seen in the second half of Table 5-4. The fibre was further degritted and opened to a minimum surface area of 6000 cm^2/g. This resulted in significantly different test data. The reground material

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was somewhat shorter than the fibre concentrate. At the lower surface areas, crudy fibre settled out in the Bauer-McNett tanks, falsely indicating a longer fibre length distribution. Opening the fibre to a minimum surface area eliminated this occurrence.

In order to keep a consistent Bauer-McNett, the test was performed in the following manner for the remainder of this study:

1. A weighed sample of fibre was fluffed and pulled apart by hand to allow the grit to be removed. The percentage of grit was calculated.

2. The surface area of the degritted fibre was measured. If required, the fibre sample was opened to a minimum surface area of 6000 cm^2/g. All samples were kept as close to this surface area as possible.

3. A standard Bauer-McNett length distribution was determined.

4. The 4 and 14 mesh screen fractions from the Bauer-McNett test were examined for grit. If present, a second grit removal (from the paper) was conducted and the Bauer-McNett recalculated.

5.2 PRELIMINARY GRINDING STUDIES

It was decided that further grinding tests were to be conducted on two separate fractions of the fibre free ore. A screen analysis of the elutriation cone I underflow from sample II indicated a +4 mesh screen fraction of 49%. The underflows from the two elutriation cones were combined with the concentrating table middlings and screened on the 4 mesh screen cloth.

5.2.1 Hardinge Ball Mill Grinding Tests

The +4 and -4 mesh screen fractions were riffled into samples of approximately 40 lbs. for grinding tests in the Hardinge ball mill. A two foot diameter mill was used, operating at 95% of the critical RPM.

A series of grinding tests were conducted on the Hardinge mill in order to the determine the effects of grinding time and slurry densities on the fibre recovery and quality for both the +4 and -4 mesh screen fractions. The charge to feed ratio was 10:1 with a 40 lb. feed. The mill used 1 1/2" ϕ steel balls. Mill conditions, fibre extraction and quality determinations are shown in Table 5.5.

The effect of grinding time on fibre recovery and quality was consistent in both the +4 and -4 mesh fractions. Longer grinding times produced more fibre concentrate. Rock reduction was also greater for both fractions with increasing grinding times. This is shown in the decreasing decanted heavies and the increasing trommel underflows by the Canmet fibre assay method.

The Bauer-McNett length determinations indicated that fibre shortening took place with increased grinding times in the +4 mesh sample, as shown by the Acc +14 mesh fraction and the -200 mesh fraction. This did not seem to occur in the -4 mesh sample. The length was similar in the 5 and 10 minute grind products. The 20 minute grind was visually inspected before a fibre assay was taken, and considered too fine for further processing.

The pulp density has no consistent effect on the fibre quality or recovery. The pulp density did affect the surface area of the fibre product. Higher surface areas in the +4 mesh fibre products resulted from increasing pulp densities.

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TABLE 5-5

HARDINGE BALL MILL GRINDING TESTS

Feed Size	Mill Conditions		Canmet Fibre Assay (WT%)					Fibre Quality						
	Grinding Time (min.)	% Solids Feed	Decanted Heavies	Trommel Unders	Concentrating Table			Surface Area (cm^2/g)	Bauer-McNett (WT%)					
					Tailings	Middlings	Concentrate (Recovery)		+4	+14	Acc +14	+35	+200	-200
+4 mesh	5	60	83.8	8.7	5.0	0.2	2.0	12,000	14	16	30	18	34	18
	10	60	66.3	17.6	10.0	3.8	2.3	--	--	--	--	--	--	--
	15	60	52.0	28.0	17.5	0.1	2.4	13,600	3	10	13	19	40	28
	5	60	83.7	6.3	6.3	0.6	3.1	10,700	7	11	18	13	25	44
	5	40	74.5	8.4	13.4	1.3	2.4	8,500	10	14	24	15	29	32
	5	30	80.6	6.7	8.4	1.5	2.8	5,900	8	9	17	10	22	51
-4 mesh	5	60	56.3	11.8	26.3	0.6	5.0	5,800	5	11	16	19	32	33
	10	60	23.6	21.0	42.3	5.0	8.1	6,800	8	13	21	17	32	30
	20	60	0	--	--	--	--	--	--	--	--	--	--	--

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The Hardinge ball mill grinding tests indicated that the lower pulp densities may be beneficial to the fibre product because they do not significantly open the fibre. The lower pulp densities would also ease unloading and material transfer through the mill.

The shorter grinding times were considered appropriate for all further testing. Longer times indicated fibre destruction and would, therefore, not be used.

5.2.2 Preliminary Rod Charge-Ball Charge Comparison

In order to directly compare different grinding systems, it was necessary to conduct tests, where possible, on equipment of the same size, scale, capacity, etc. A 12" diameter x 11" mill was obtained in order to conduct both rod and ball mill grinding tests. Samples of approximately 5 lb. were ground and evaluated using the bench scale fibre assay method. Test conditions and mill results are shown in Table 5-6.

The rod mill produced a consistently higher fibre recovery than the ball mill under equivalent conditions. Fibre quality tests were not conducted on these samples due to their small quantity. It was concluded that larger scale tests would be conducted to confirm these results, and to evaluate alternative methods of grinding.

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TABLE 5-6

PRELIMINARY GRINDING TESTS - STANDARD MILL

Mill Type/ Charge	Charge: Feed	% Solids Feed	Grinding Time	Bench Scale Fibre Assay Rock	Fibre	-100 Mesh
Ball Charge: 1 1/2" balls**	20:1	20	4	92.9	3.5	3.6
Ball charge: 1 1/2" balls	10:1	30	4	96.0	2.3	1.7
Rod charge: 10 @ 2"ϕ x 11"**	20:1	20	4	91.2	3.9	4.9
Rod charge: 9 @ 2"ϕ x 11"	10:1	30	4	94.2	4.0	1.8
Rod charge: 2 @ 2 1/2"ϕ x 11"* 1 @ 2"ϕ x 11"	10:1	20	4	97.3	1.4	1.3

* Rod charge was insufficient for proper grinding
** The 20:1 charge to feed ratio in the 20% solids mill feeds were required to allow for the large volume of water

5.3 Formal Bench Scale Tests

A series of tests were conducted in order to compare the relative merits of the rod, ball, attrition and Szego mills. Testing was done on samples of approximately 50 lbs. In order to have a consistent feed to the grinding mills, a third barrel of material, designated Sample III, was processed through the fibre extraction circuit. The mill and quality test results are shown in Table 5-7.

The mass balances from this sample correlate quite well with those of Sample II. The percentage of the material rejected by the elutriation cones in both samples was identical. There was less than a 1% difference between the concentrating table rejects (middlings and

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TABLE 5-7

MILL AND QUALITY TEST RESULTS - SAMPLE III

(Rod Milling of cone underflow)

FIBRE EXTRACTION CIRCUIT (WT%)						FIBRE QUALITY						
Elutriation Cone		Trommel	Concentrating Table			Surface Area (cm^2/g)	Bauer-McNett (WT%)					
CONE I	CONE II	Unders	Tailings	Middlings	Concentrate (Recoveries)		+4	+14	Acc +14	+35	+200	-200
86.0	0.9	5.9	4.6	0.1	2.5	5800	17	18	35	22	31	12

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tailings). Fibre recoveries were also quite similar (2.2% vs 2.5%). The roping reported on the table in Sample II was eliminated in Sample III by agitating the table feed. The length distribution of the two fibre concentrates given by the Bauer-McNett are identical when adjusted to a common dust level.

The consistency of the mass balances in these two samples suggest that the sampling procedures were fairly consistent at this size of sample. The cone underflows and middlings were screened on the 4 mesh screen cloth to give an oversized fraction (73%) which was used in the formal bench scale tests.

Grinding tests were conducted on the ball mill, rod mill, attrition mill, and Szego mill under the conditions described in Table 5-8. The batch mills were of the same scale and capacity, allowing for direct comparison. The Szego mill, although of the same physical size had a much higher capacity. The three batch mills had a capacity of 120 lb./hr (8 lb. batch in a 4 minute grind). The Szego mill was fed at higher rates. The three batch mills (ball, rod, attrition) had the same grinding time of 4 minutes. Fibre liberation and quality in the mills were determined and are summarized in Table 5-9.

The ball and rod mill grinds had similar fibre recovery and quality, but the rod mill did have a higher fibre recovery in the 20% solids test. The dust adjusted Bauer-McNett length classification indicated that the fibre quality of the two mills was the same.

The attrition mill gave significantly higher recoveries in both the autogenous and media grinding tests. Fibre quality tests indicated that both produced fibre of poorer quality than the rod or ball mills. The attrition media grinding test was of the poorest quality. It also tended to be an unpractical method of grinding since the media was of the same size as the gangue material, requiring a more complicated method of separating rock and media than in the other mills.

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TABLE 5-8

STANDARD GRINDING TEST CONDITIONS

Mill	Test No.	Charge	Charge/ Feed	% Solids Feed	Feed Rate lb./hr.	TOTAL Feed (lb.)	MILL RPM
Ball Mill	1	1 1/2" Balls	20:1	20	N/A	30	52
	2	1 1/2" Balls	10:1	30	N/A	40	52
Rod Mill	1	2"ϕ x 11" Rods	20:1	20	N/A	25	52
	2	2"ϕ x 11" Rods	10:1	30	N/A	40	52
Attrition Mill	1	Autogenous	N/A	30	N/A	40	560
	2	1/4 " Balls	10:1	30	N/A	10	560
Szego Mill	1	N/A	N/A	30	660	5	600
	2	N/A	N/A	30	2,200	5	600
	3	N/A	N/A	43	1,760	10	300
	4	N/A	N/A	43	1,760	10	450
	5	N/A	N/A	43	1,760	560	450

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TABLE 5-9

BENCH SCALE FIBRE RECOVERY AND QUALITY

Mill	Test No.	CANMET FIBRE ASSAY					FIBRE QUALITY						
		Decanted Heavies	Trommel Unders	Concentrating Table WT% Tailings	Middlings	Concentrate (Recovery)	Surface Area (cm^2/g)	Bauer-McNett (WT%) +4	+14	Acc +14	+35	+200	-200
Ball Mill	1	88.3	9.0	1.2	0.3	1.2	6000	14	21	35	21	30	14
	2	95.8	1.4	1.4	0.2	1.2	5900	17	19	36	17	30	17
Rod Mill	1	84.0	11.2	0.7	0.9	3.2	6000	10	16	26	16	29	28
	2	92.5	5.6	0.5	0.2	1.2	7600	14	16	30	17	29	24
Attrition Mill	1	87.5	6.7	3.3	0	2.5	11,000	8	13	21	17	33	29
	2	65.0	20.9	5.1	1.0	8.0	11,700	2	4	6	7	34	53
Szego Mill	1	65.3	17.9	10.5	0.8	5.5	6000	8	11	19	11	26	42
	2	--	--	--	--	--	--	-	--	--	--	--	--
	3	88.9	3.4	5.4	0.4	1.9	7200	19	20	39	21	28	12
	4	72.5	9.0	14.8	0.4	3.3	9300	8	16	24	22	34	20
	5	68.6	18,5	9.7	0.3	2.9	8000	8	15	23	19	39	19

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The Szego mill discharged a finer sized product at slower feed rates and at a faster rotation speed. The initial Szego test was conducted at its slowest rotational speed (600 rpm) and at a low feed rate (300 kg/hr) in an effort to match, as closely as possible, the capacity of the fibre extraction circuit. The mill discharge was much too fine (by visual inspection) to be classified in the fibre extraction circuit, so a determination of fibre quality and recovery was not done. A second test at the maximum feed rate for the given feed pulp density was conducted. Fibre recovery was significantly higher than in the other mills, although quality was reduced.

The Szego mill tended to grind the feed material much more than necessary. The drive system was modified so that the mill could run at a lower rotational speed than the original design. Two additional small tests (approximately 50 lb. samples) were conducted at rotational speeds of 300 and 450 RPM. A feed, pulp density of 43% solids was used for each test. The fibre recovery from the two tests was, again, significantly higher than the rod and ball mill.

Because of the consistently higher fibre recoveries from the Szego mill grinding tests, a larger (560 lbs.) test of the Szego mill grinding product was conducted. A feed of 43% pulp density was ground at the General Comminution facilities. The mill product was drained, transported back to the Ontario Research Pilot plant, and processed through the fibre extraction circuit.

5.4 Bench Scale Test Conclusions

The bench scale grinding tests indicated that the rod mill was potentially the best method of wet asbestos comminution. It gave a slightly greater amount of fibre recovery than the ball mill, with the same quality. The attrition mill produced more recoverable fibre, but it was of much poorer quality. There was a significant decrease in length.

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The Szego milled material proved to have greater fibre liberation than both the rod and ball mills. However, the Szego mill produced the shortest fibre length distribution material, as determined by the Bauer-McNett. The fibre was also significantly shorter than the dry processed material. The Szego mill was fed and operated under optimum conditions to provide the least amount of fibre shortening. This suggested that the Szego mill was not as efficient at freeing fibre without losing length.

The Hardinge ball mill tests indicated that significant fibre recovery came from the -4 mesh material. Although the fibre recovered from the -4 mesh fraction was shorter than the +4 mesh recovery, it was of sufficient quantity that it could not be discarded. It was concluded that the elutriation cone underflows and the middlings product from the free fibre extraction circuit would be processed through the rod mill to recover the unliberated fibre.

6. PILOT SCALE TESTING

A pilot scale grinding test was conducted using a rod mill. A Hardinge cylindrical rod mill (2' diameter x 3 feet) was installed in front of the fibre extraction circuit such that the mill discharged directly into the first elutriation cone, thereby eliminating the need for a material transfer system. The rod mill could be bypassed in order to provide a free fibre extraction operation, and then be used in front of the circuit to provide the comminution needed for the unliberated fibre.

6.1 Free Fibre Extraction

The pilot scale, free fibre extraction was done on twenty barrels of mill feed material. They were passed through the roll crusher set at a 1/2 inch gap, and processed over the fibre extraction circuit to remove the free fibre at a feed rate of 200 lb./hr.

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The free fibre extraction was done on a semi-batch basis, resulting in 20 samples being collected. The average test results of these twenty samples was used for analysis.

Table 6-1 shows the mass balance and fibre quality measurements for the free fibre extraction circuit. The various fractions and products generated by the circuit (elutriation cone unders, concentrating table products, trommel unders) are quite consistent with Samples II and III processed through the circuit. The Bauer-McNett fibre length determinations for the 20 barrel pilot plant run was also very consistent with Sample III.

6.2 Unliberated Fibre Extraction

Pilot scale grinding of the elutriation cone underflows and the concentrating table middlings to recover the unliberated fibre, proceeded in two stages. The first stage was the preliminary testing of the large rod mill used in the pilot scale run. The second stage was the pilot scale rod mill test.

The Hardinge rod mill used in the first stage of grinding tests was loaded with 577 lbs. of 2" diameter rods, 30 inches long and occupying approximately 15% of the mill volume. The mill was rotated at 75% of its critical speed. Feed to the mill was kept constant at 200 lbs. per hour of solid material in order to keep the milling compatible with the fibre extraction circuit.

The mill was evaluated using three different feed pulp densities. Each test was run for 30 minutes to equilibrate the mill and fibre extraction circuit, followed by a 15 minute fibre sampling period. Because the 30 minute equilibration time did not produce proper product, mass balances were not determined for these tests. The fibre quality was determined and compared. Results are shown in Table 6-2. The feed

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TABLE 6-1

PILOT SCALE FIBRE RECOVERY AND QUALITY

SAMPLE	FIBRE EXTRACTION CIRCUIT (WT%)							FIBRE QUALITY (WT%)						
	WT (lbs.)	Elutriation Cone Underflow		Trommel Unders	Concentrating Table			Surface Area cm^2/g	Bauer-McNett					
		Cone I	Cone II		Tailings	Middlings	Concentrate		+4	+14	Acc +14	+35	+200	-200
Free Fibre Extraction	11,207	87.5	1.0	4.7	4.1	0.1	2.6	8230	13	19	32	23	30	15
Unliberated Fibre Extraction	1,800	70.1	4.1	12.1	10.4	0.1	3.2	6650	10	16	26	20	56	18

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Table 6-2

Rod Mill Tests

Feed Rate lb./hr	% Solids	Mill RPM	Grit Content %	Surface Area cm^2/g	Degritted Bauer-McNett WT% +4	+14	Acc.+14	+35	+200	-200
87	36	40	4.3	6400	14	16	30	19	30	21
91	50	40	9.6	9300	7	15	22	19	38	21
91	60	40	2.9	10700	9	14	23	20	38	19

density of 36% solids gave the best quality fibre product. The 50% and 60% solids feed density showed some fibre shortening, as well as fibre of a higher surface area. The 60% solids feed material also tended not to be as free flowing as the lower pulp feed densities. A rod mill feed of 36% solids was chosen for the pilot scale grinding test. Fed at this rate, the ore had a retention time of 18.7 minutes in the rod mill (see Appendix A for calculations).

6.2.1 Pilot Scale Rod Mill Test

The pilot scale rod mill test had an actual running time of 10 hours, processing 1960 pounds of elutriation cone underflow and middlings products. The processing was sampled over four periods. The results from these samples were averaged. Fibre extraction circuit mass balances and fibre quality test data are shown in Table 6-1.

7. WET AND DRY CIRCUIT COMPARISON

The relative advantages and disadvantages of the wet and dry circuit can be only partially compared since the energy and capacities of the dry circuit was beyond the scope of this study. These and other parameters, however, have been determined for the wet fibre extraction circuit and mill. Where possible, direct comparisons between the two processes were made.

7.1 Energy Consumption

The energy consumption of the wet circuit was determined by power consumption measurements of the individual machines in the fibre extraction circuit and the rod mill. Instantaneous power consumption readings were taken for all machines running with and without material passing through them. In all cases, except for the rod mill, the power readings did not change. There was no fluctuation in the power consumptions during operation, so instantaneous readings were taken. The circuit had an operating capacity of 200 lbs./hr. The readings were adjusted to give measurements of KWH/short ton.

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Table 7-1 lists the contribution of energy consumption for each of the operating units used. The components of the fibre extraction circuit shown in Figure 4-1, total 15.13 KWH/Ton of ore processed. This measured power was expended to produce a free fibre concentrate. Using the pilot scale results from Table 7-1 it can be seen that 88.6% of the ore (elutriation cone underflows and the concentrating table middlings) was reprocessed through the rod mill and fibre extraction circuit to free and collect the unliberated fibre.

The total energy consumption of the free and unliberated fibre extraction operation, per ton of ore feed was calculated in the following manner:

Energy Consumption (KWH/Ton)	Circuit
15.13	Fibre Extraction Circuit
14.00	Rod Mill

(Free Fibre) = Fibre Extraction Circuit
Energy Consumption = 15.13 KWH/Ton

(Unliberated Fibre)
Energy Consumption = .886 (Rod Mill & Fibre Extraction Circuit)
= .886 (14.00 + 15.13)
= 25.81 KWH/Ton

Total Energy Consumption = 40.94 KWH/Ton

7.2 Wet Circuit Capacity and Throughput

A direct comparison between the commercial dry mill and the pilot scale wet mill could not be made since the dry mill data was not provided to Ontario Research. The capacities and throughputs of the wet pilot mill was determined. This could in turn be upscaled to provide an estimate of capacity.

Figures 7-1 and 7-2 show the capacities of the fibre extraction circuit used to recover the free fibre, and the rod mill - fibre extraction circuit used to recover the unliberated fibre respectively. If the two are considered to be in series, total capacity would be 90 kg per hour. Water consumption would be 6498 ℓ/hr.

7.3 Fibre Recovery and Quality Comparisons

When comparing the products of the wet and dry mills, both the fibre quality and recovery were examined. Three different products were evaluated for each mill: free fibre, fibre liberated by rod milling and a blend of the two. The blend was proportioned to the recovery of the two fibre products. Samples of both the wet and dry processed fibre were sent to LAQ and the College de la Region de l'Amiante in Thetford Mines for testing to confirm the results.

Table 7-2 lists the recovery and fibre quality data for the dry milled and wet milled fibre samples (using the rod mill). The top section of the table displays the results obtained from the actual testing of the fibre. The recoveries of the free fibre are almost identical. There was, however, more fibre liberated by wet milling than by dry. Length distributions obtained by the Bauer-McNett test indicated similar lengths, but approximately twice as much dust (-200 mesh material) was found in the dry milled fibre samples. The difference in the dust levels was also indicated in the FSU results. The wet processed fibre consistently gave higher (stronger) results than the dry processed material.

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Table 7-2 lists the fibre recovery and quality data for the wet and dry mills from all three laboratories. Generally, the correlation between the three laboratories was quite good. Ontario Research tended to report shorter Bauer-McNett values than the College, and the College had significantly lower surface areas. Fibre strength unit correlations between the three laboratories was fair. The college tended to have higher FSU results for both the wet and dry free fibre products than the other two laboratories. The unliberated fibre FSU tests varied in all three laboratories.

The quality tests indicated differences between the wet and dry processed fibre. Surface areas tended to be higher and dust levels tended to be lower in the wet processed material. Fibre strength was also increased in the wet process.

Varying amounts of dust tend to mask, somewhat, the comparisons of fibre quality and quantity between samples. This effect can be minimized by a mathematical dust adjustment to a common dust level. Fibre recoveries and length fractions in the Bauer-McNett test can be proportionately adjusted with the removal or addition of dust. A common dust level of 30% was chosen. Results are shown in the bottom half of Table 7-3. Given a common dust level (30% minus 200 mesh), there was significantly higher recoveries in the circuit than in the dry (6.9% vs. 5.2%). The wet circuit, however, produced fibre that was slightly shorter than the dry process. The Bauer-McNett classifier results typically have an error associated with them of approximately $\pm$2.5%. A 5% difference in the Bauer-McNett would be considered marginal. These differences exceed that limit by 1%.

These tests indicate that the wet circuit gives a greater fibre recovery of slightly shorter, but much cleaner and stronger fibre than the dry process.

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TABLE 7-1

ENERGY CONSUMPTION

Process	Equipment	Instantaneous Energy (WH)	Energy Consumption KWH/TON
Fibre Extraction Circuit	Vibratory Feeder	36	0.36
	Attrition Mixer	426	4.26
	Trommel Screen	180	1.80
	Concentrating Table	500	5.00
	Sala Pump	272	2.72
	Sweco Screen	99	0.99
Grinding	Rod Mill (Empty)	1300	--
	(Full)	1400	1400
Free Fibre Extraction			15.13
Unliberated Fibre Extraction			40.94

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TABLE 7-2

FIBRE RECOVERY AND QUALITY

	ONTARIO RESEARCH			LAQ		COLLEGE	
	Free Fibre	Unliberated Fibre	Blend	Free Fibre	Unliberated Fibre	Free Fibre	Unliberated Fibre
Dry Process Surface Area (cm^2/g)	6800	5800	6400	7000	5800	5650	3350
Bauer-McNett(WT%)							
+4	14	13	13	11	10	13	10
+14	16	16	16	16	16	17	18
Acc +14	30	29	29	27	26	30	28
+35	22	25	22	21	22	22	25
+200	17	12	16	19	17	20	15
-200	31	34	33	33	35	28	33
Recovery(WT%)	-	-	-	2.7	2.8	-	-
FSU	103	82	91	104	90	114	100
MR_A	326	243	287	-	-	295	278
Wet Process Surface Area (cm^2/g)	9200	6800	8300	8900	6600	2270	2450
Bauer-McNett(WT%)							
+4	12	10	12	13	14	19	15
+14	17	18	16	21	16	20	16
Acc +14	29	28	28	34	30	39	31
+35	23	17	21	19	17	21	19
+200	32	39	32	27	38	28	34
-200	16	16	19	20	15	13	16
Recovery(WT%)	2.6	3.2	5.8	-	-	-	-
FSU	113	96	97	111	88	115	90
MR_A	281	236	246	-	-	259	269

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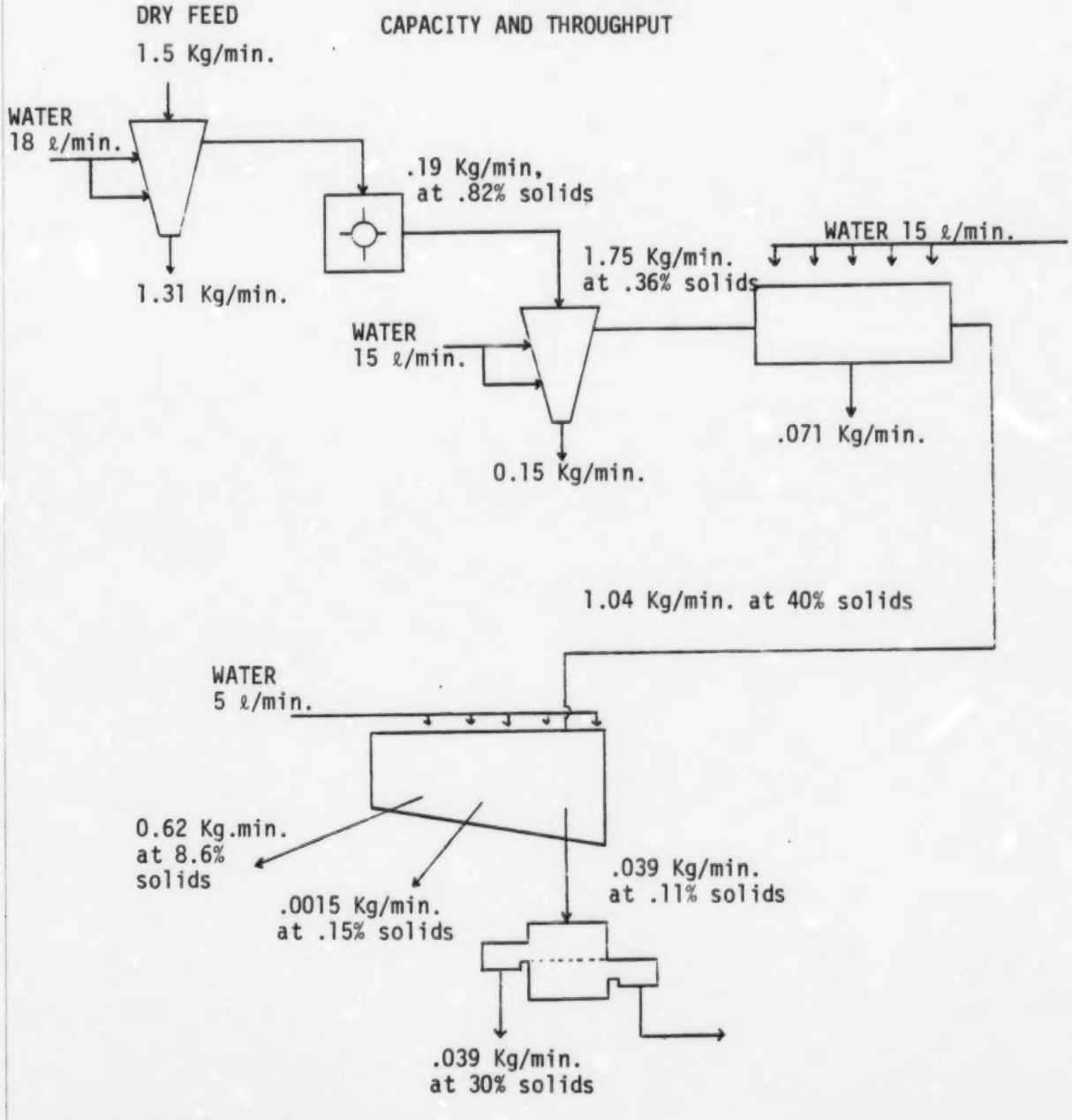
TABLE 7-3

DUST ADJUSTED FIBRE
RECOVERY AND QUALITY

	ONTARIO RESEARCH			LAQ		COLLEGE	
	Free Fibre	Unliberated Fibre	Blend	Free Fibre	Unliberated Fibre	Free Fibre	Unliberated Fibre
Dry Process Bauer-McNett(WT%)							
+4	14	14	13	11	11	13	11
+14	16	16	17	17	17	16	19
Acc +14	30	30	30	28	28	29	30
+35	23	27	23	22	24	22	26
+200	17	13	17	20	18	21	15
-200	30	30	30	30	30	30	30
Recovery(WT%)	-	-	-	2.6	2.6	-	-
Wet Process Bauer-Mcnett(WT%)							
+4	10	8	10	11	12	15	12
+14	14	15	14	18	13	16	13
Acc +14	24	23	24	29	25	31	25
+35	19	14	18	17	14	17	16
+200	27	33	28	24	31	22	28
-200	30	30	30	30	30	30	30
Recovery(WT%)	3.1	3.8	6.9	-	-	-	-

FIGURE 7-1

FIBRE EXTRACTION CIRCUIT
CAPACITY AND THROUGHPUT

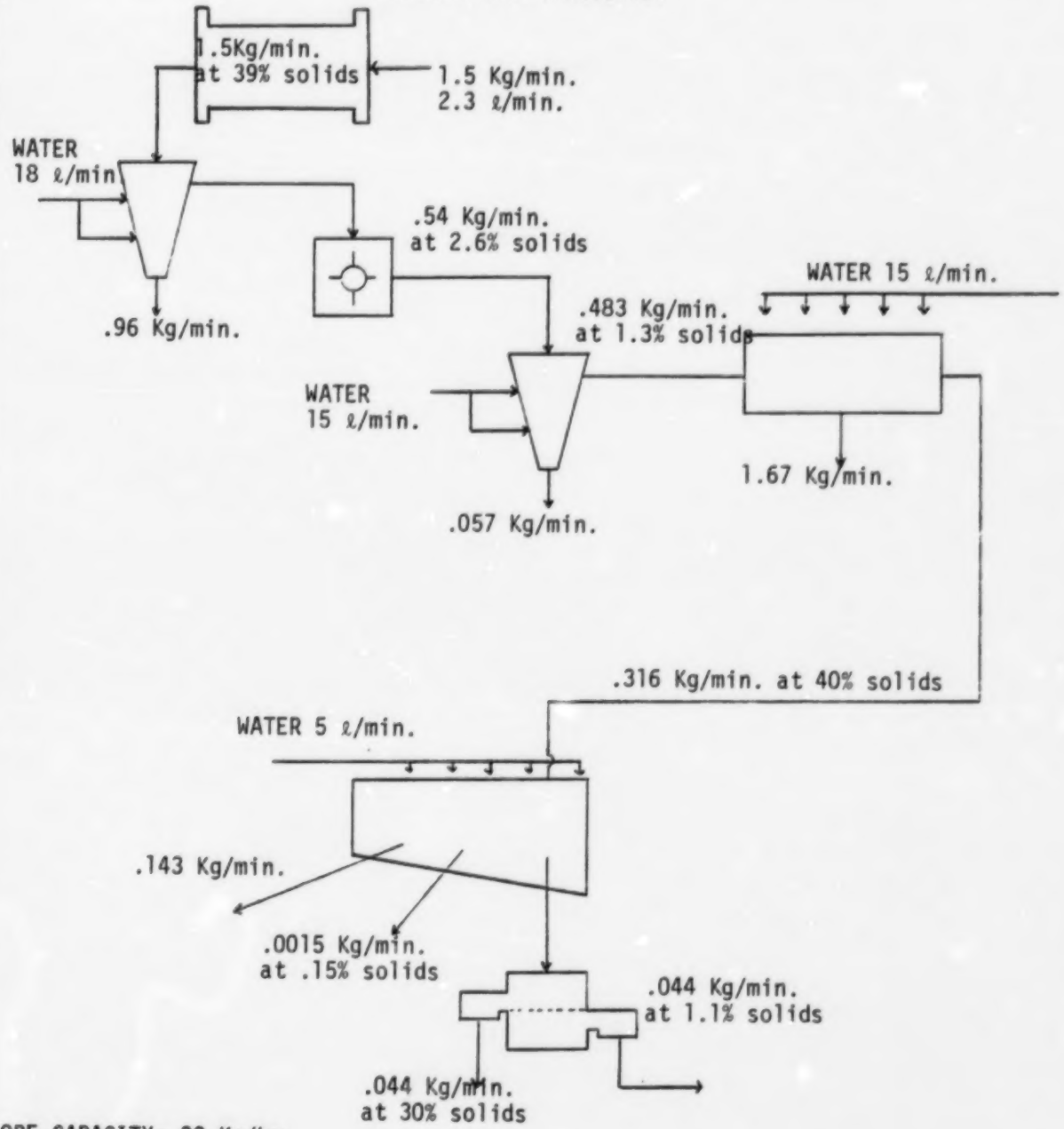


ORE CAPACITY: 90 Kg/hr.

WATER CONSUMPTION: 3180 ℓ/min.

ORF

FIGURE 7-2
ROD MILL REGRIND CIRCUIT
CAPACITY AND THROUGHPUT



ORE CAPACITY: 90 Kg/hr.

WATER CONSUMPTION: 3318 ℓ/hr.

8. CONCLUSIONS

The wet mill and fibre extraction circuit provided a greater recovery than the dry mill tested. The wet milled fibre was slightly shorter, cleaner (less -200 mesh content), and stronger, by the Fibre Strength Unit test.

The rod mill was proven to be the best mill of the four mills tested (rod, ball, attrition, Szego). The criteria used was the quantity and quality of fibre recovered by the milling methods.

M. L. Petrovcic
Project Scientist
Non-Metallic Minerals

C. A. Booth
Section Manager
Non-Metallic Minerals

:mw

ORE

APPENDIX A

MISCELLANEOUS FLOWSHEETS AND FIGURES

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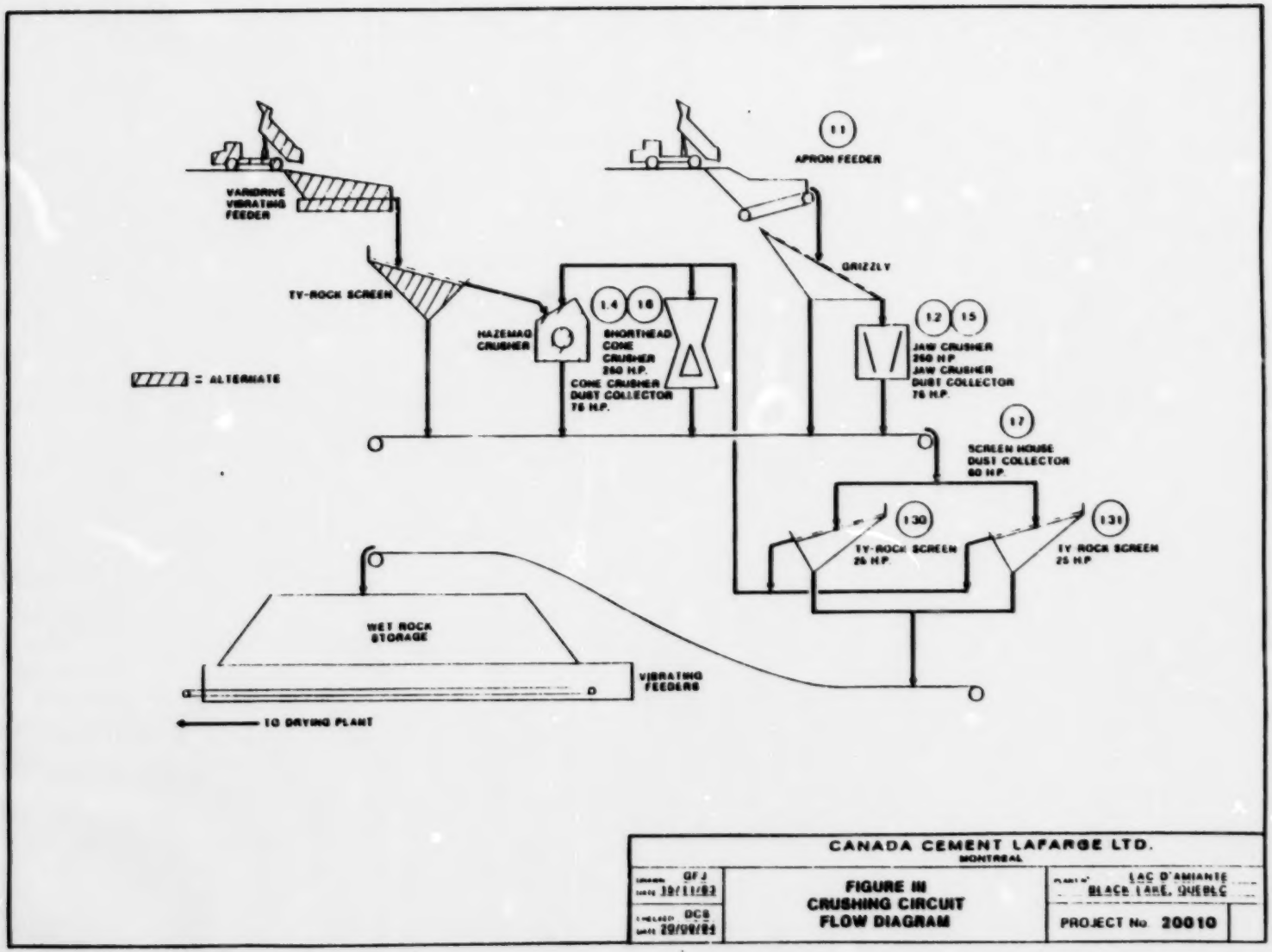

CANADA CEMENT LAFARGE LTD. MONTREAL		
DRAWN GFJ DATE 30/11/83	FIGURE III CRUSHING CIRCUIT FLOW DIAGRAM	PLANT LAC D'AMIANTE BLACK LAKE, QUEBEC
CHECKED DCG DATE 29/12/83		PROJECT No 20010

FIGURE 1
MILL BENEFICIATION CIRCUIT
-CRUSHING STAGE

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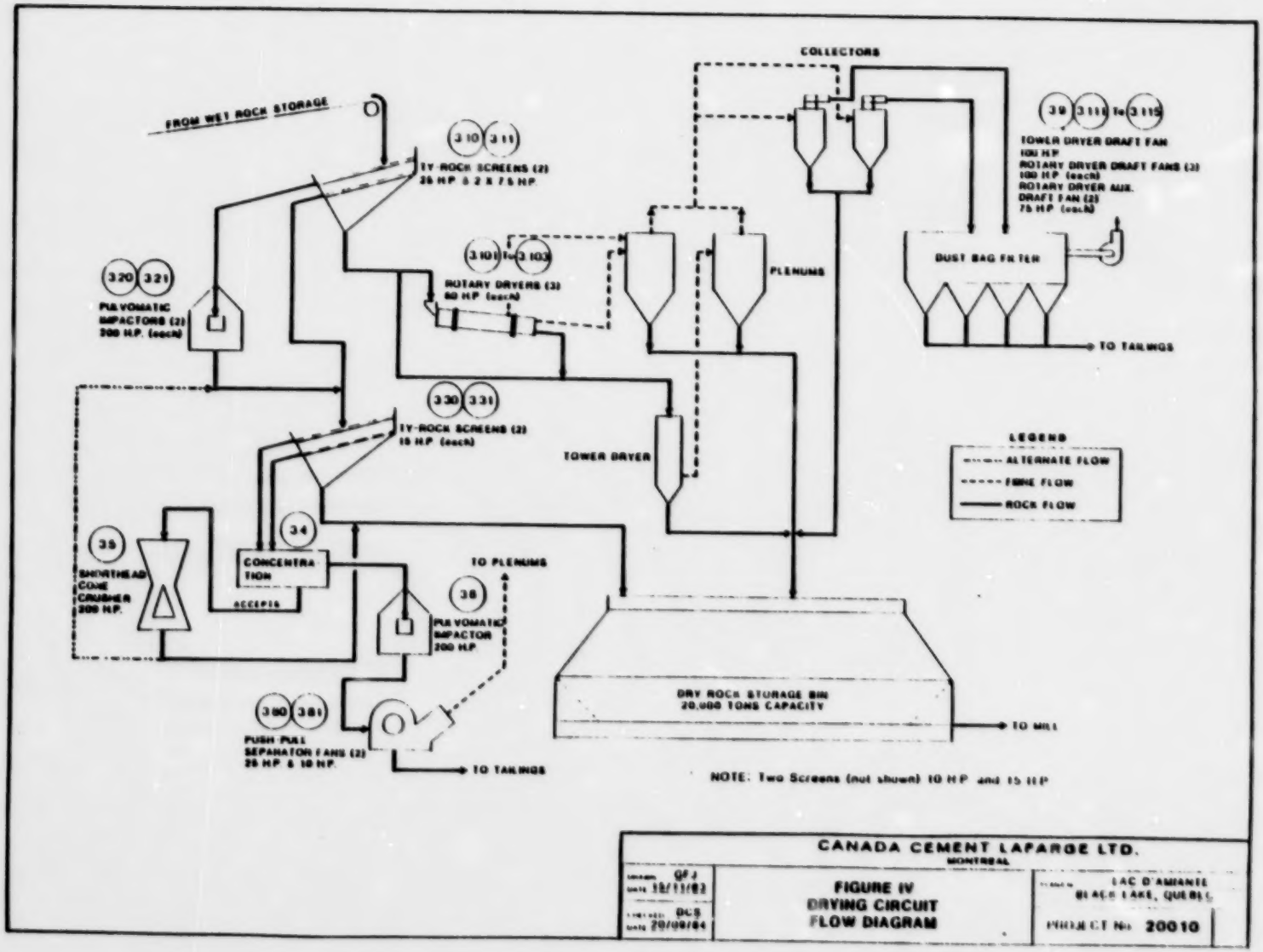

FIGURE 2
MILL BENEFICIATION CIRCUIT
-DRYING STAGE

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FIGURE 3

SMALL CORE DRY MILL

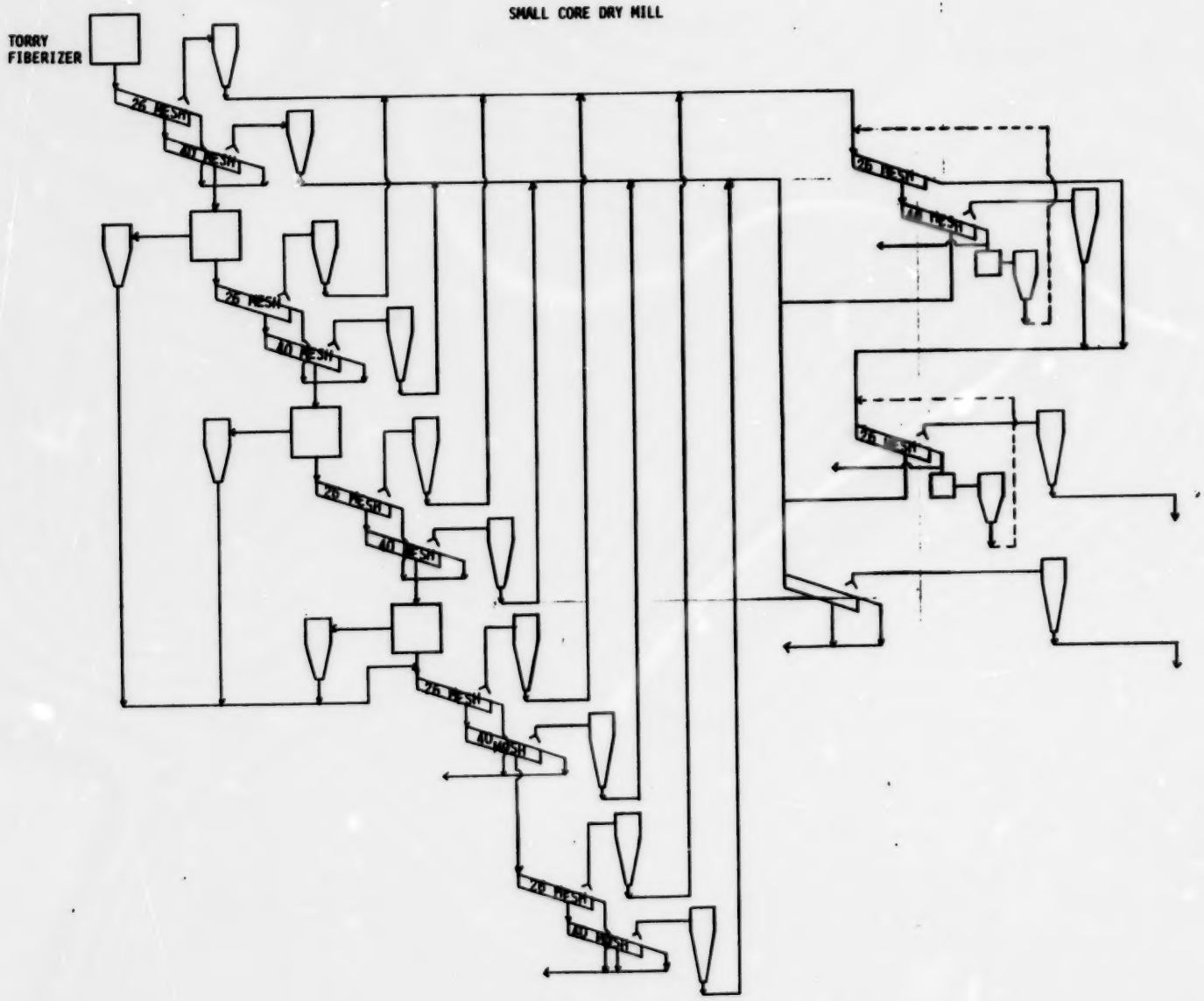

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FIGURE 4

FIBRE EXTRACTION CIRCUIT

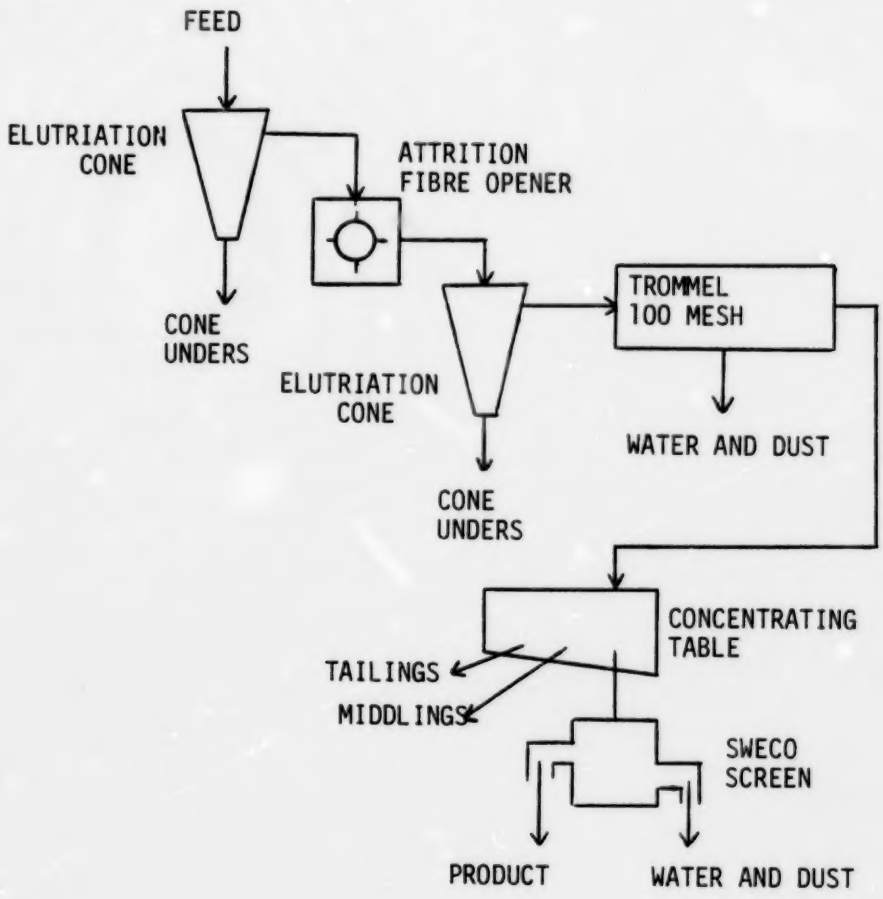


FIGURE 5

CANMET FIBRE ASSAY

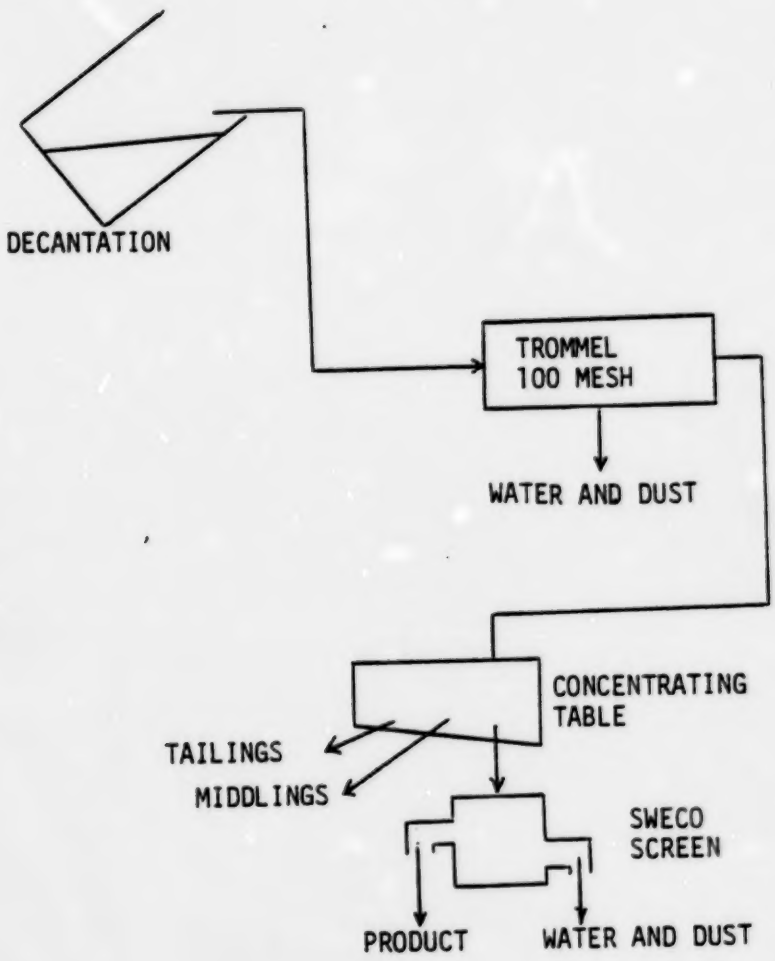
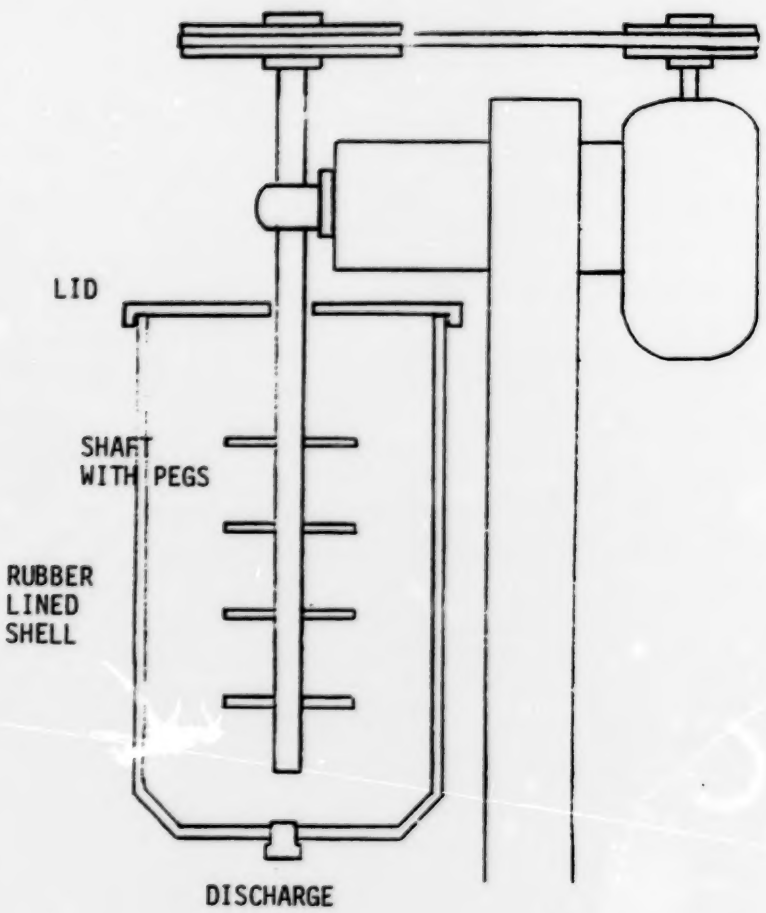
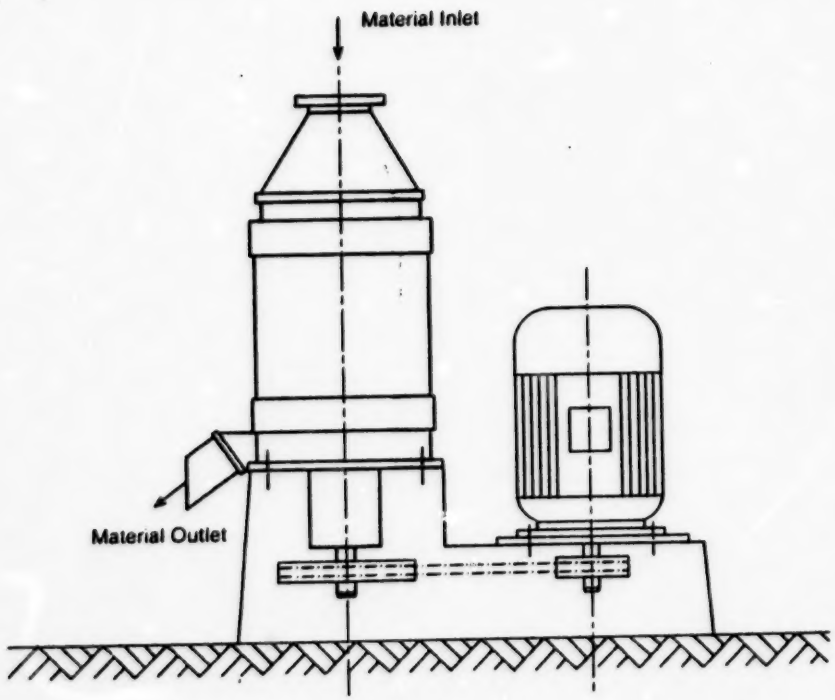


FIGURE 6

ATTRITION MILL





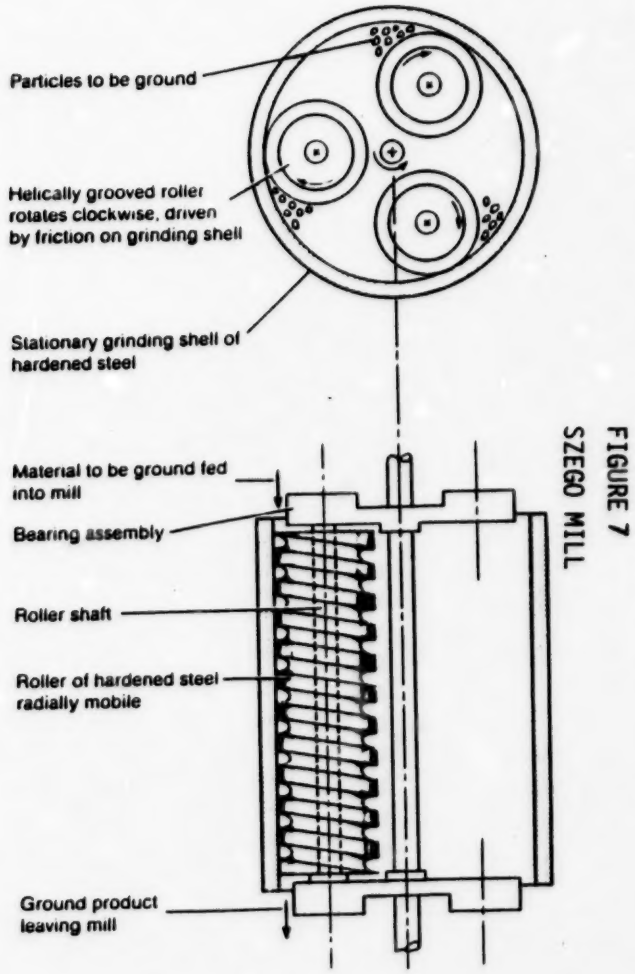

Particles to be ground
Helically grooved roller rotates clockwise, driven by friction on grinding shell
Stationary grinding shell of hardened steel
Material to be ground fed into mill
Bearing assembly
Roller shaft
Roller of hardened steel radially mobile
Ground product leaving mill

FIGURE 7
SZEGO MILL

ORE

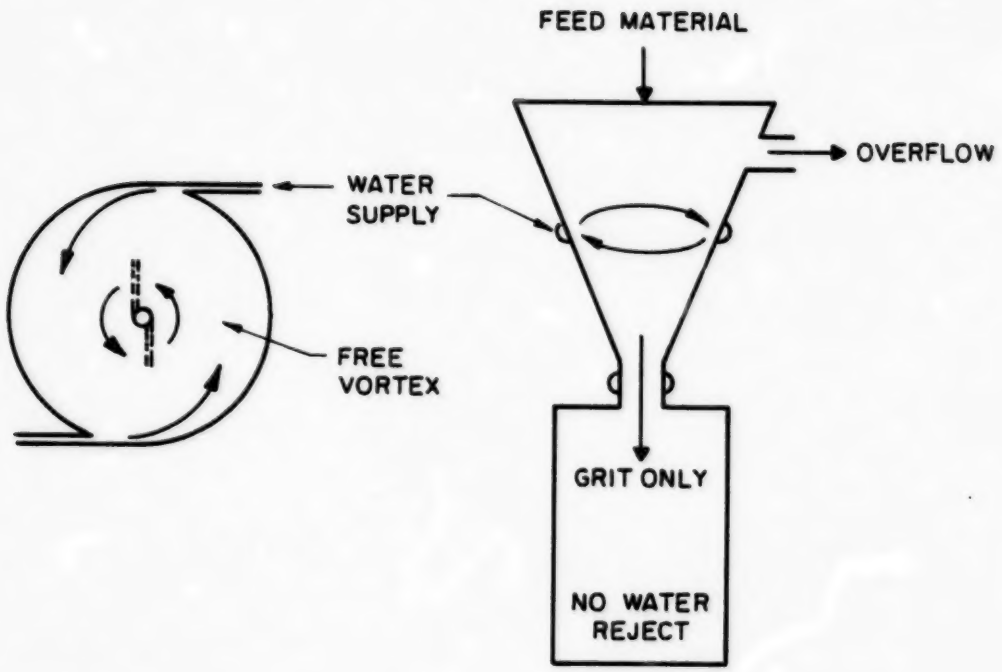


FIGURE 8 ELUTRIATION CONE

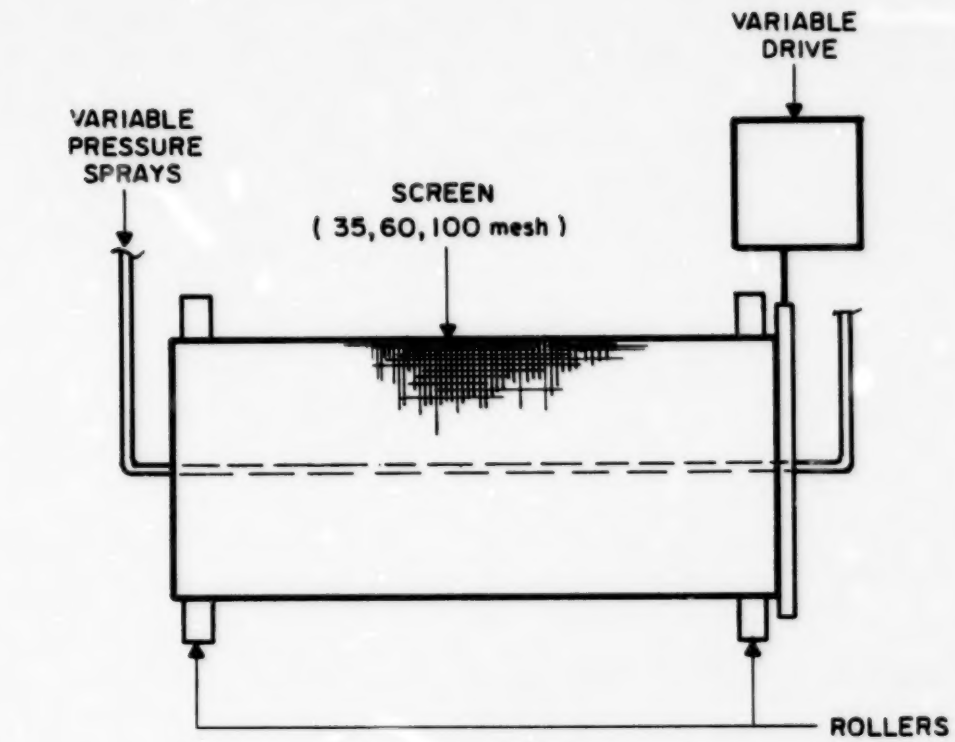


FIGURE 9 TROMMEL DEWATERING AND DEDUSTING SCREEN

FIGURE 10

SWECO DEDUSTING AND DEWATERING SYSTEM

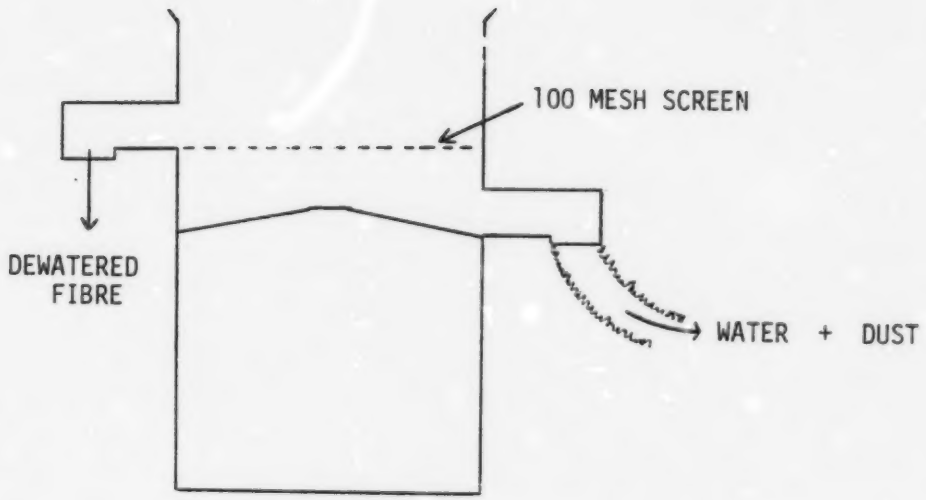


FIGURE 11

ATTRITION FIBRE OPENER

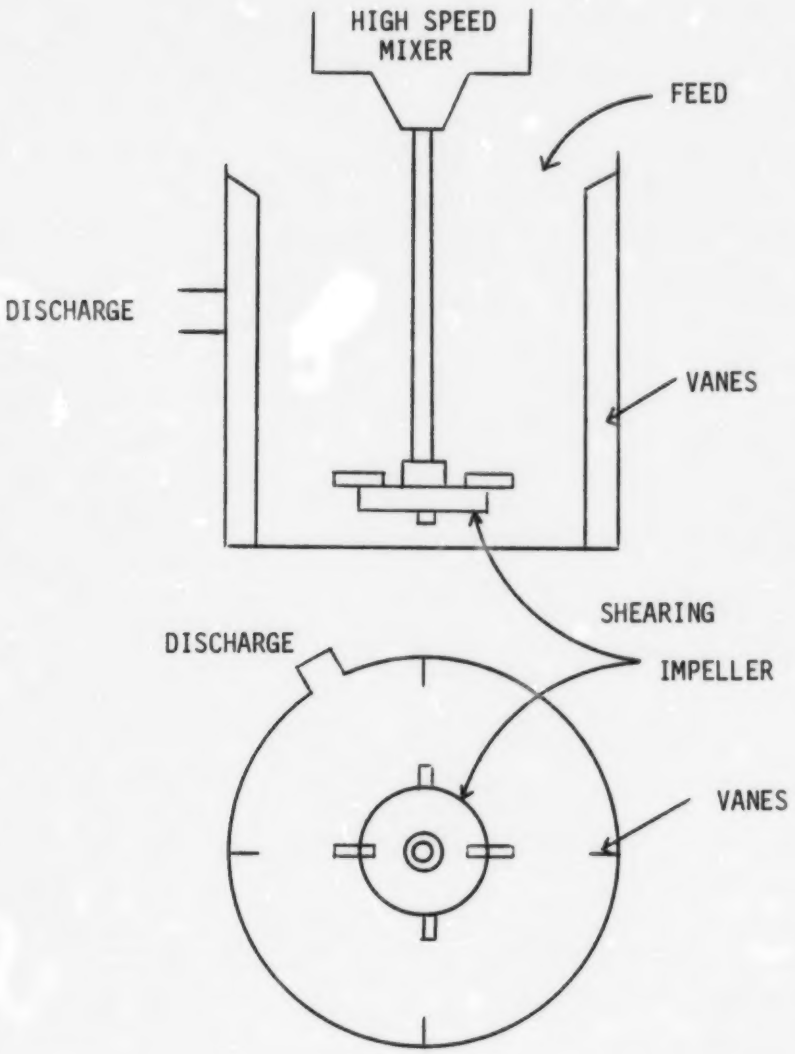


FIGURE 12

CONCENTRATING TABLE

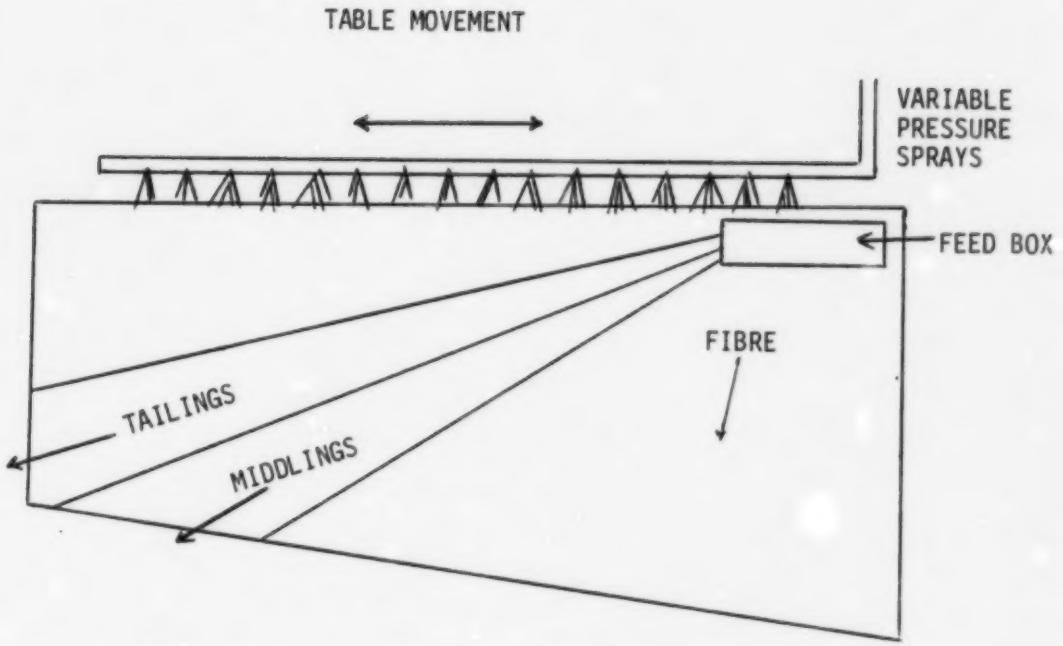
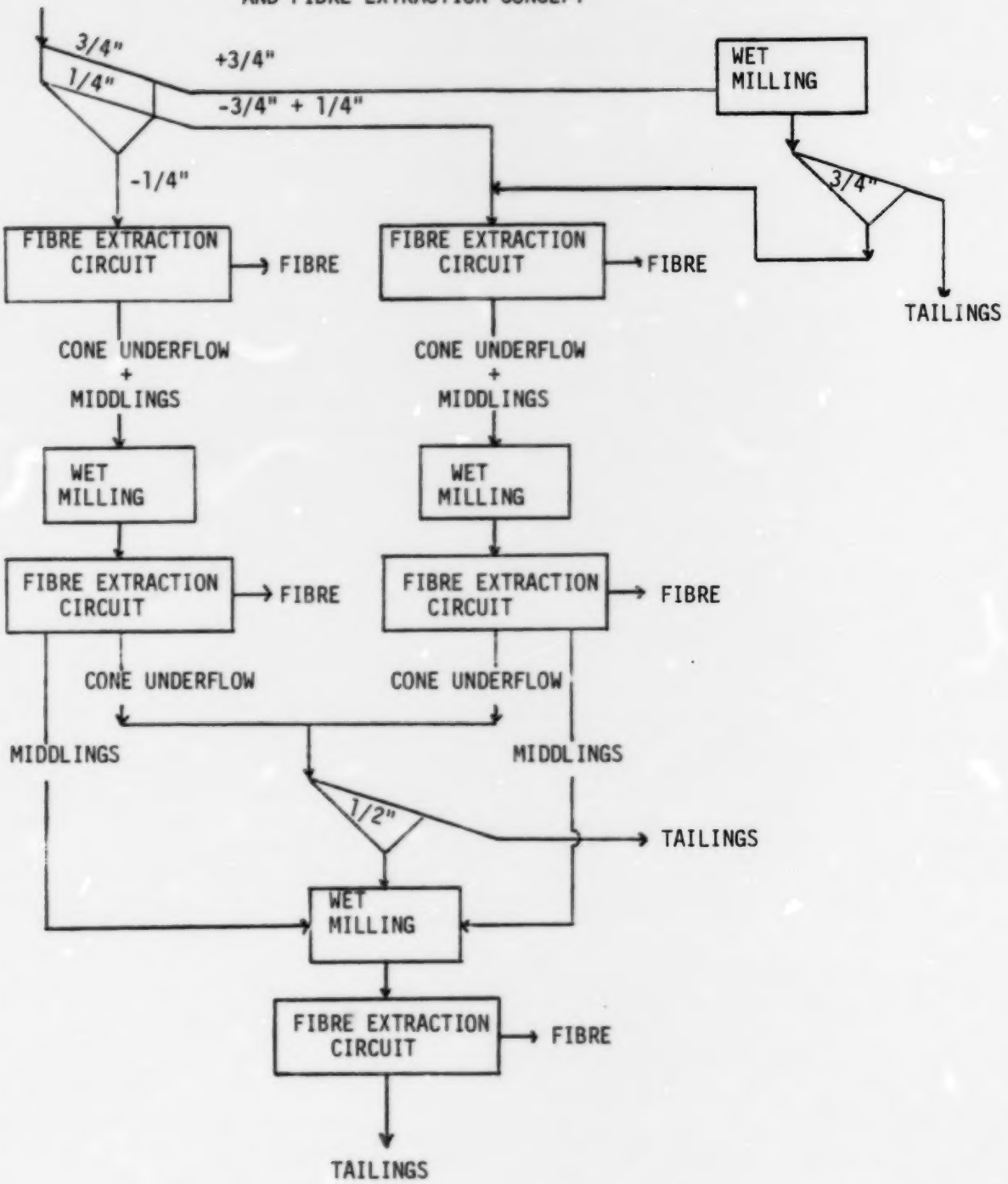


FIGURE 13

MULTI-STAGE GRINDING
AND FIBRE EXTRACTION CONCEPT



ORI

Kilborn Ltd.
Final Report No. 64-10510

HARDINGE BALL MILL RETENTION TIME CALCULATION

MILL DIMENSIONS	2.8' x 2.0'
VOLUME OF MILL	$= L \pi R^2$
	$= 8.7$ ft.^{3}
VOLUME BELOW TRUNION	$= .4 \times 8.7$
	$= 3.48$ ft.^{3}
VOLUME OF STEEL	$= 57$ lb. $\div 493.4$ lb./ft.^{3}
	$= 1.17$ ft.^{3}
VOLUME OF SLURRY IN MILL	$= 2.31$ ft.^{3}
DENSITY OF SLURRY	$= 74.78$ lb./ft.^{3}
SLURRY WEIGHT IN MILL	= 172.93 lb. @ 36% solids
SOLIDS WEIGHT IN MILL	= 62.25 lb.

FEED RATE 200 lb./hr

RETENTION TIME = 18.7 min.

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APPENDIX B

Lac d'Amiante du Quebec, Ltee

College de la Region de l'Amiante

Test Results

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Lac d'Amiante du Quebec, Ltee

ORF

FORM: QC-18

LAC D'AMIANTE D ' QUEBEC, LTEE

DIVISION BLACK LAKE DIVISION

CONTROLE DE LA QUALITE — QUALITY CONTROL

RESULTATS DE TESTS EN LABORATOIRE — LABORATORY RESULTS

CLIENT OU DEPARTEMENT
CUSTOMER OR DEPARTMENT

DATE: 20 Août 1986

ECHANTILLON - SAMPLE (GRADE)	FIBRE LIBRE	NON FIBRE LIBIREE	FROZEN	FREE & FROZEN	FREE
ENSACHAGE - BAGGING	(Mineraie	traité par LAQ)	(Mineraie traité par L'ONTARIO		
COMMANDE - ORDER NO.			RESEARCH FOUNDATION)		
WAGON - CAR NO.	26 Mesh	26 Mesh			
TONNES - TONS	40 "	40 "			
DATE			#1	#2	#3
QUART - SHIFT					
STANDARD (1 LB. - 1 MIN. 50 SEC.)			Sur 8 ozs		Sur 8 ozs
1/2 PO. - INCH.			0.3 (Boules)		0.5 (Boules)
4 M.	7.9	5.7	3.0	PAS	3.8
10 M.	4.8	5.9	2.6	ASSEZ DE	2.0
35 M.	2.0	2.5	0.6	FIBRE	0.6
PAN	1.3	1.9	1.5		1.1

ROTAP	4 + 5	6 + 7D	7
GR/MIN.	50/10	100/10	100/30

M.	3	4	6	6	2.4	0.6	11.4	30.0	25.6
M.	4	6	10	14	7.8	4.6	16.6	17.0	17.2
M.	6	10	14	20	17.6	14.4	19.0	15.0	16.0
M.	10	20	20	28	26.2	26.2	19.0	13.0	15.0
M.	20	35	35	35	19.0	18.6	5.4	5.0	5.6
M.	35	65	65	65	15.8	16.8	6.4	5.6	6.4
PAN	PAN	PAN	PAN		11.2	18.8	22.2	14.4	14.2

MC NETT (20 MIN.)						
20 GR.	10 GR.					
14 M.	4 M.	11.0	10.0	14.0	13.0	13.0
35 M.	14 M.	16.0 27.0	16.0 26.0	16.0 30.0	17.0 30.0	21.0 34.0
00 M.	35 M.	21.0	22.0	17.0	19.0	19.0
00 M.	200 M.	19.0	17.0	38.0	34.0	27.0
00 M.	-200 M.	33.0	35.0	15.0	17.0	20.0
ESSAI DE LAVAGE WASH TEST - 200 M. (%)		32.0	37.0	14.0	15.0	18.0

GRIT % (100 GR.)	1.4	2.3	4.1	3.9	2.4
PARTICULES +20M. ROCK PARTICLES	1	5	2	3	8
BATONNETS +20 M. U.F.P.	M	M	N	M	M
CONTENU ROCHEUX (%) ROCK CONT.					
VOL. A SEC. DRY BULK (100 GR.) C.C.					
VOL. A L'EAU WET BULK (30 GR.-2 HRS) C.C.	880	600	1060	1270	1300
VOL. A L'EAU WET BULK (20 GR.-4 HRS) C.C.	660	440	800	880	960
VISCOSITE - VISCOSITY					
KEROSENE C.C. 100 GR.	514	446	456	PAS DE FIBRE	498
PENETRATION	181.8	172.4	214.8	236.1	257.2
DRAINAGE - FILTRATION (SEC.)	43	26	143	89	68
SURFACE - B.S.A. ($CM.^2$ / GR.)	7000	5800	6600	8600	8900
COULEUR - COLOR	58.5	54.0	60.0	65.0	67.0
T.S.U. (IND.) TEST	104.3	90.3	88.4	104.0	110.8
P.V. COMPLET	67.8	57.8	56.4	67.6	72.5

REMARQUES - REMARKS

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College de la Region de l'Amiante

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Centre spécialisé en technologie minérale

Le 22 août 1986

	Qf	MRA	FSU	FSU corrigé
Fibre libérée # 86-1566	9.7	294.9	109.8	114.2
Fibre non libérée # 86-1566	10.5	278.2	96.2	100.0
½ - ½ free and frozer May 26-86	9.8	264.9	98.7	102.6
Free fibre blend # 1 à # 20 May-26-86	9.2	259.4	110.7	115.0
Frozer fibre # 1 à #4 June-10-86	11.3	268.8	86.7	90.2

COLLÈGE DE LA RÉGION DE L'AMIANTE
671, boulevard Smith sud, Thetford-Mines, QC. G6G 1N1 — Tél.: (418) 338-8591 ou 338-8595

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GRADE	Fibre libérée				
Echantillon	#86-1566				
Trou de forage #					
Longueur					
ESSAI STANDARD DU QUEBEC					
1/2 po					
4M					
10M					
35M					
Panne					
Rotap 4-5 6-7D 7					
McNett	1	2	Moyenne (1 & 2)		
10 gr.	%	%	%		
4M	13.3	13.1	13.2		
14M	16.7	17.5	17.1		
35M	21.8	21.2	21.5		
200M	20.6	20.1	20.4		
-200M	27.6	28.1	27.8		
ESSAI DE LAVAGE -200M					
Teneur en faisceaux bruts					
Particules rocheuses					
Bâtonnets					
Drainage					
Perméabilité à l'air (RSA)	56.5 DM2/GM				
Couleur					
F.S.U. Ind.					
F.S.U. Réel					
REMARQUES					

ORF

GRADE	Fibre non libérée				
Echantillon	# 86-1566				
Trou de forage #					
Longueur					
ESSAI STANDARD DU QUEBEC					
1/2 po					
4M					
10M					
35M					
Panne					
Rotap 4-5 6-7D 7					
McNett	# 1	# 2	Moyenne (1 & 2)		
10 gr.	%	%	%		
4M	9.8	9.8	9.8		
14M	17.7	18.6	18.2		
35M	25.3	23.8	24.5		
200M	15.2	14.6	14.9		
-200M	32.0	33.2	32.6		
ESSAI DE LAVAGE -200M					
Teneur en faisceaux bruts					
Particules rocheuses					
Bâtonnets					
Drainage					
Perméabilité à l'air (RSA)	33.5DMZ/GM				
Couleur					
F.S.U. Ind.					
F.S.U. Réel					
REMARQUES					

ORF

25-08-86

GRADE	Free and frozen ¼ -½				
Échantillon	May-26-86				
Trou de forage #					
Longueur					
ESSAI STANDARD DU QUEBEC					
1/2 po					
4M					
10M					
35M					
Panne					
Rotap 4-5 6-7D 7					
McNett	1	2	Moyenne (1 et 2)		
10 gr.	%	%	%		
4M	16.9	14.9	15.9		
14M	18.3	18.2	18.3		
35M	18.4	20.7	19.5		
200M	32.3	29.7	31.0		
-200M	14.1	16.5	15.3		
ESSAI DE LAVAGE -200M					
Teneur en faisceaux bruts					
Particules rocheuses					
Bâtonnets					
Drainage					
Perméabilité à l'air (RSA)	27.2 DM^2 / GM				
Couleur					
F.S.U. Ind.					
F.S.U. Réel					
REMARQUES					

ORF

25-08-86

GRADE	Free fibre blend				
Echantillon	# 1 à #20				
Trou de forage #	May-26-86				
Longueur					
ESSAI STANDARD DU QUEBEC					
1/2 po					
4M					
10M					
35M					
Panne					
Rotap 4-5 6-7D 7					
McNett	1	2	Moyenne (1 et 2)		
10 gr.	%	%	%		
4M	18.9	18.1	18.5		
14M	19.6	20.0	19.8		
35M	19.6	21.4	20.5		
200M	29.5	26.5	28.0		
-200M	12.4	14.0	13.2		
ESSAI DE LAVAGE -200M					
Teneur en faisceaux bruts					
Particules rocheuses					
Bâtonnets					
Drainage					
Perméabilité à l'air (RSA)	22.7 DM^2 / GM				
Couleur					
F.S.U. Ind.					
F.S.U. Réel					
REMARQUES					

ORF

GRADE	Froze.nFibre				
Echantillon	# 1 à # 4				
Trou de forage #	June-10-86				
Longueur					
ESSAI STANDARD DU QUEBEC					
1/2 po					
4M					
10M					
35M					
Panne					
Rotap 4-5 6-7D 7					
McNett	1	2	Moyenne (1 et2)		
10 gr.	%	%	%		
4M	14.7	14.7	14.7		
14M	16.2	15.2	15.7	30 4	
35M	18.5	19.5	19.0	19	
200M	34.9	32.9	33.9	33 4	
-200M	15.7	17.7	16.7		
ESSAI DE LAVAGE -200M					
Teneur en faisceaux bruts					
Particules rocheuses					
Bâtonnets					
Drainage					
Perméabilité à l'air (RSA)	24.5 DM^2 /GM				
Couleur					
F.S.U. Ind.					
F.S.U. Réel					
REMARQUES					

ORF

GRADE	Froze.nFibre				
Echantillon	# 1 à 4				
Trou de forage #	June-10-86				
Longueur					
ESSAI STANDARD DU QUEBEC					
1/2 po					
4M					
10M					
35M					
Panne					
Rotap 4-5 6-7D 7					
McNett	1	2	Moyenne (1 et2)		
10 gr.	%	%	%		
4M	14.7	14.7	14.7		
14M	16.2	15.2	15.7	30.4	
35M	18.5	19.5	19.0	49	
200M	34.9	32.9	33.9	33.9	
-200M	15.7	17.7	16.7		
ESSAI DE LAVAGE -200M					
Teneur en faisceaux bruts					
Particules rocheuses					
Bâtonnets					
Drainage					
Perméabilité à l'air (RSA)	24.5 DM^2 /GM				
Couleur					
F.S.U. Ind.					
F.S.U. Réel					
REMARQUES					

ORF

RESISTANCE DE LA FIBRE D'AMIANTE
DANS UN PRODUIT AMIANTE-CIMENT

RESULTAT 11-08-86

ECHANTILLON	NO	CHARGE DE RUPTURE	EPAISSEUR				DIMENSION ELEMENTS	MODELE DE RUPTURE (MRT)	POIDS HUMIDE		VOLUME (C.C.) (S.I.)	POIDS SEC GRMS	DENSITE AJUSTEE	FORCE EN FLEXION (MRA)
			A	B	C	MOY.			SAT.	IMM.				
2 01		33.5	5.75	5.73	5.72	5.73		305.7	178.0	89.5	88.5	145.6	1.645	289.2
2 02		33.6	5.70	5.69	5.71	5.70		310.2	177.6	89.2	88.4	145.3	1.644	294.0
2 03		34.8	5.75	5.74	5.73	5.74		316.9	177.6	89.2	88.4	145.2	1.643	300.7
2 04		34.3	5.77	5.72	5.77	5.75		310.9	178.5	89.2	89.3	145.6	1.630	299.4
2 05		35.0	5.81	5.75	5.80	5.79		313.6	179.4	90.3	89.1	147.0	1.650	294.9
2 06		32.4	5.76	5.74	5.74	5.75		294.3	177.6	88.0	89.6	143.5	1.602	293.8
2 07		33.8	5.85	5.80	5.78	5.81		300.4	181.0	90.4	90.6	146.9	1.621	292.5
2 08		33.5	5.85	5.73	5.73	5.77		301.9	179.9	89.5	90.4	145.4	1.608	298.7
2 09		34.0	5.84	5.83	5.90	5.86		297.4	180.6	89.8	90.8	146.4	1.612	292.8
2 10		32.0	5.73	5.71	5.75	5.73		292.4	177.5	87.9	89.6	143.2	1.598	293.0
Moyenne		33.7	5.78	5.74	5.76	5.76		304.4	178.8	89.3	89.5	145.4	1.625	294.9

L.A.Q. Fibre libérée 86-1566

Qf. RATIO 9.7

$$\frac{275 \times 0.097 \times 100}{(1.00-0.097) \times 294.9} + 275 \times 0.097$$

Q.f. Req 9.1

1000/9.1

FSU 109.8

FSV corrigé: 109.8X1.04=114.2

Final M.R.A. 298.9

Min. 272.8

Max. 317.0

ORF

RESISTANCE DE LA FIBRE D'AMIANTE
DANS UN PRODUIT AMIANTE-CIMENT

RESULTAT 11-08-86

ECHANTILLON	NO	CHARGE DE RUPTURE	EPAISSEUR				DIMENSION ELEMENTS	MODELE DE RUPTURE (MRT)	POIDS HUMIDE		VOLUME (C.C.) (S.I.)	POIDS SEC GRMS	DENSITE AJUSTEE	FORCE EN FLEXION (MRA)
			A	B	C	MOY.			SAT.	IMM.				
3 01		28.0	5.68	5.61	5.70	5.66		261.9	174.4	86.5	87.9	141.0	1.604	260.6
3 02		31.5	5.71	5.65	5.66	5.67		293.6	177.3	88.3	89.0	143.9	1.617	287.5
3 03		31.5	5.73	5.72	5.79	5.75		286.2	177.7	88.2	89.5	143.9	1.608	283.4
3 04		32.2	5.65	5.63	5.77	5.68		299.1	176.8	88.0	88.8	143.3	1.614	294.0
3 05		29.5	5.71	5.71	5.68	5.70		272.4	175.9	87.2	88.7	142.0	1.601	272.1
3 06		32.3	5.77	5.65	5.70	5.71		297.5	178.8	89.3	89.5	145.4	1.625	288.6
3 07		31.6	5.73	5.65	5.72	5.70		291.8	178.7	89.2	89.5	145.5	1.626	282.6
3 08		31.0	5.71	5.73	5.70	5.71		284.9	178.6	89.0	89.6	145.4	1.623	277.0
3 09		32.9	5.70	5.64	5.71	5.68		305.6	175.3	89.7	85.6	145.9	1.704	269.3
3 10		31.1	5.74	5.70	5.83	5.76		281.5	180.4	90.4	90.0	147.9	1.643	266.9
Moyenne		31.2	5.74	5.70	5.83	5.70		287.5	177.4	88.6	88.8	144.4	1.626	278.2

Fibre non libérée
L.A.Q. # 86-1566

Qf RATIO 10.5 %

$\frac{275 \times 0.105}{(1.00-0.105)X_{278.2}} \times 100 + 275 \times 0.105$

Q.f Req 10.4

1000/0.4

F.S.U. 96.2

FSU corrigé: 96.2X1.04=100.0

Final M.R.A. 278.2

Min. 257.3

Max. 299.1

ORF

RESISTANCE DE LA FIBRE D'AMIANTE
DANS UN PRODUIT AMIANTE-CIMENT

RESULTAT 11-08-86

ECHANTILLON	NO	CHARGE DE RUPTURE	EPAISSEUR				DIMENSION ELEMENTS	MODELE DE RUPTURE (MRT)	POIDS HUMIDE		VOLUME (C.C.) (S.I.)	POIDS SEC GRMS	DENSITE AJUSTEE	FORCE EN FLEXION (MRA)
			A	B	C	MOY.			SAT.	IMM.				
4 01		30.8	5.88	5.83	5.87	5.86		269.1	180.8	89.2	91.6	146.2	1.596	270.4
4 02		31.4	5.86	5.80	5.79	5.82		278.4	181.8	90.8	91.0	148.5	1.632	267.7
4 03		29.0	5.77	5.77	5.89	5.81		257.7	180.0	89.7	90.3	146.4	1.621	251.0
4 04		32.0	5.74	5.75	5.81	5.77		288.7	180.8	90.8	90.0	148.3	1.648	272.2
4 05		31.3	5.85	5.85	5.85	5.85		274.4	179.8	89.5	90.3	145.9	1.616	269.1
4 06		29.2	5.91	5.79	5.85	5.85		256.0	179.6	88.0	91.6	143.8	1.570	265.9
4 07		29.4	5.88	5.86	5.88	5.87		255.7	183.4	89.5	93.9	146.8	1.563	267.8
4 08		30.2	5.88	5.83	5.91	5.87		262.6	180.3	89.3	91.0	145.6	1.600	262.6
4 09		30.1	5.79	5.76	5.78	5.78		270.6	180.4	89.9	90.5	146.8	1.622	263.3
4 10		30.7	5.82	5.80	5.91	5.84		269.7	179.9	90.0	89.9	146.8	1.633	259.0
Moyenne		30.4	5.84	5.80	5.85	5.83		268.3	180.7	89.7	91.0	146.5	1.610	264.9

1/2 - 1/2 free and frozer
May 26-86

Qf. RATIO 9.8 %

$$\frac{275 \times 0.098 \times 100}{+275 \times (1.00-0.098) \times 264.9 \quad 0.098}$$

Q.f. Req 10.1

1000/10.1

F.S.U. 98.7

FSU corrigé: 98.7X1.04=102.6

Final M.R.A. 264.9

Min. 245.0

Max. 284.8

ORF

RESISTANCE DE LA FIBRE D'AMIANTE
DANS UN PRODUIT AMIANTE-CIMENT

RESULTAT 11-08-86

ECHANTILLON	NO	CHARGE DE RUPTURE	EPAISSEUR				DIMENSION ELEMENTS	MODELE DE RUPTURE (MRT)	POIDS HUMIDE		VOLUME (C.C.) (S.I.)	POIDS SEC GRMS	DENSITE AJUSTEE	FORCE EN FLEXION (MRA)
			A	B	C	MOY.			SAT.	IMM.				
5 01		31.5	5.79	5.79	5.80	5.79		281.6	179.3	89.6	89.7	146.0	1.628	272.1
5 02		33.4	5.80	5.76	5.85	5.80		297.5	180.4	90.4	90.0	147.0	1.633	285.5
5 03		33.7	5.83	5.78	5.84	5.82		298.8	181.7	91.6	90.1	149.2	1.656	279.0
5 04		31.0	5.80	5.73	5.80	5.78		278.7	179.5	90.1	89.4	146.9	1.643	264.2
5 05		33.9	5.83	5.84	5.85	5.84		298.2	182.3	91.1	91.2	148.8	1.632	286.8
5 06		32.7	5.78	5.71	5.78	5.76		296.0	179.4	89.7	89.7	146.2	1.630	285.3
5 07		31.3	5.90	5.83	5.85	5.86		273.4	182.3	91.2	91.1	148.9	1.634	262.0
5 08		33.7	5.77	5.70	5.80	5.76		305.1	177.3	88.6	88.7	144.3	1.627	295.1
5 09		35.3	5.81	5.78	5.82	5.80		314.4	181.1	91.5	89.6	149.0	1.663	291.1
5 10		34.0	5.82	5.75	5.82	5.80		303.6	180.5	91.0	89.5	148.3	1.657	283.0
Moyenne		33.1	5.81	5.77	5.82	5.80		294.7	180.4	90.5	89.9	147.5	1.640	280.8

Free fibre blend May26-86
~~8.1~~ à 20

Qf RATIO 9.2

$$\frac{275 \times 0.092 \times 100}{+275 \times (1.00-0.092) \times 280.4 \quad 0.092}$$

Q.f. Req 9.0

1000/9.0

F.S.U. 110.6

FSU corrigé: 110.6X1.04=115.0

Final M.R.A. 280.8

Min. 259.8

Max. 301.4

ORF

RESISTANCE DE LA FIBRE D'AMIANTE
DANS UN PRODUIT AMIANTE-CIMENT

ECHANTILLON	NO	CHARGE DE RUPTURE	EPAISSEUR				DIMENSION ELEMENTS	MODELE DE RUPTURE (MRT)	POIDS HUMIDE		VOLUME (C.C.) (S.I.)	POIDS SEC GRMS	DENSITE AJUSTEE	FORCE EN FLEXION (MRA)
			A	B	C	MOY.			SAT.	IMM.				
6 01		30.2	5.75	5.71	5.83	5.76		272.8	178.5	89.2	89.3	145.3	1.627	263.7
6 02		30.7	5.74	5.68	5.73	5.72		281.8	176.7	88.8	87.9	144.4	1.643	267.3
6 03		31.7	5.74	5.71	5.80	5.75		287.6	177.0	88.5	88.5	144.1	1.628	277.7
6 04		30.2	5.83	5.78	5.79	5.80		269.3	178.3	87.8	90.5	143.4	1.585	274.6
6 05		30.7	5.87	5.86	5.88	5.87		267.3	180.2	88.4	91.8	144.7	1.576	275.4
6 06		30.5	5.80	5.77	5.80	5.79		272.9	177.6	87.5	90.1	143.1	1.588	277.0
6 07		29.4	5.92	5.82	5.97	5.90		253.1	181.4	89.5	91.9	146.2	1.591	256.0
6 08		30.7	5.77	5.83	5.77	5.79		274.7	178.9	89.1	89.8	144.8	1.612	270.5
6 09		29.2	5.87	5.81	5.81	5.83		257.7	179.4	89.3	90.1	145.1	1.610	254.4
6 10		31.3	5.80	5.74	5.88	5.81		278.5	180.6	90.1	90.5	146.8	1.622	271.0
Moyenne		30.5	5.81	5.77	5.83	5.80		271.6	178.9	88.8	90.0	144.8	1.608	268.8

RESULTAT 11-08-86

Frozer fibre
1 à 4 June 10-86

Qf RATIO 11.3

275 x 0.113 x 100
(100-0.113)868.8 + 275 x 0.113

Q.f. Req 11.5

1000/115

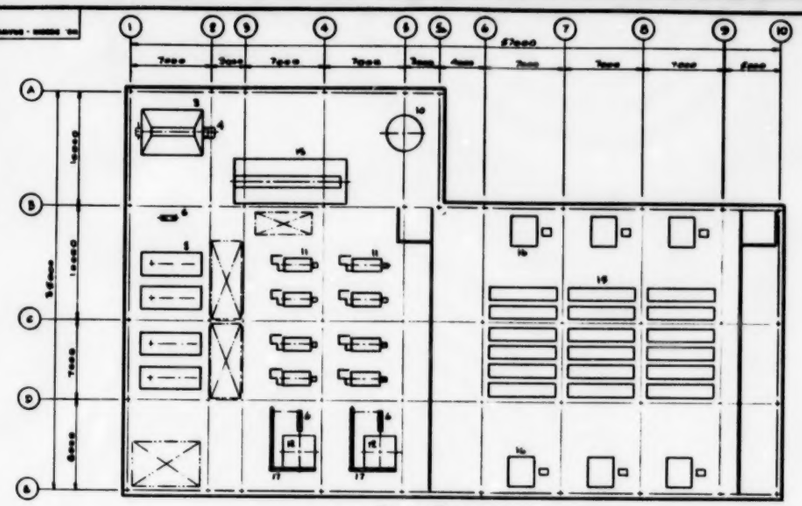
FSU 86.7

FSU corrigé:86.7X1.04=90.2

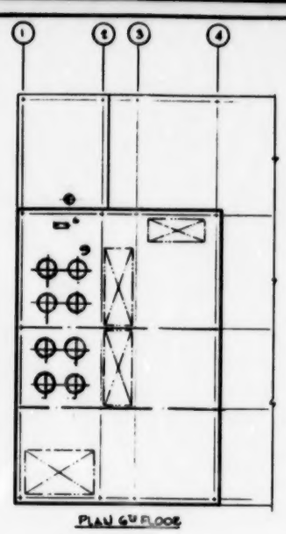
Final M.R.A 268.8
Min. 268.6
Max. 268.9

ORF

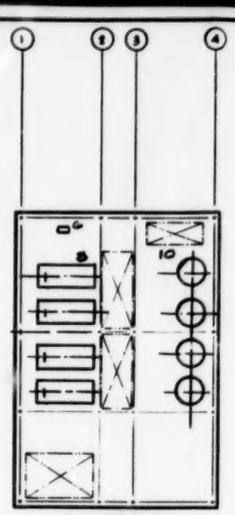
APPENDIX B



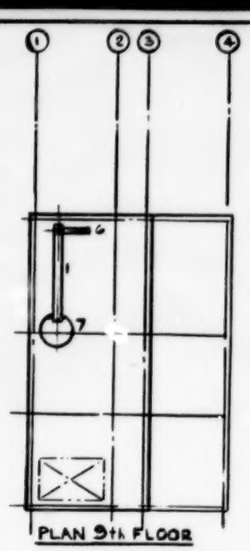
PLAN 3RD FLOOR



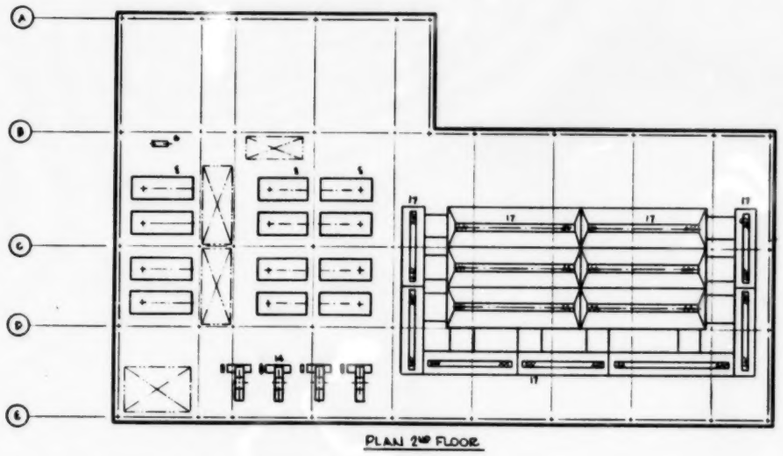
PLAN 6TH FLOOR



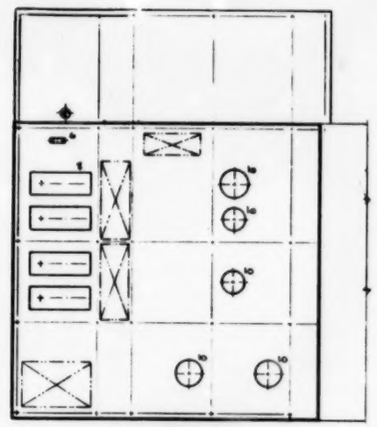
PLAN 8TH FLOOR



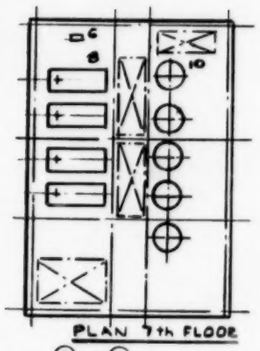
PLAN 9th FLOOR



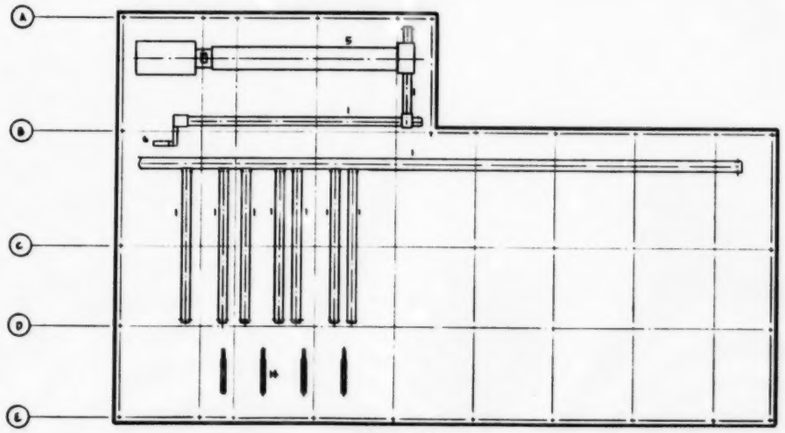
PLAN 2ND FLOOR



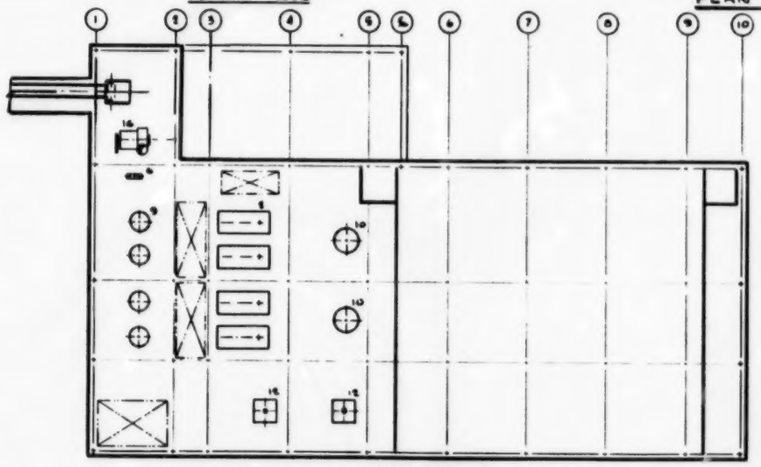
PLAN 5TH FLOOR



PLAN 7th FLOOR



PLAN 1ST FLOOR



PLAN 4TH FLOOR

EQUIPMENT LEGEND

1. BELT CONVEYOR
2. DOUBLE DECK SCREEN
3. SURGE BIN
4. BELT FEEDER
5. ROTARY DRYER
6. BUCKET ELEVATOR
7. 4-WAY DISTRIBUTOR
8. GYRATORY SCREEN
9. FIBERIZER
10. CYCLONE
11. DEDUSTER
12. PRODUCT BIN
13. TURBO FIBERIZER
14. BAGGING MACHINE
15. DUST COLLECTOR
16. FAN
17. SCREW CONVEYOR

DESCRIPTION — DESSINS DE REFERENCE - REFERENCE DRAWINGS

DESCRIPTION — REVISIONS

DESCRIPTION — REVISIONS

DESCRIPTION — REVISIONS

GENERAL LAYOUT

AUG 82

CLIENT: CAUMET / LAFARGE

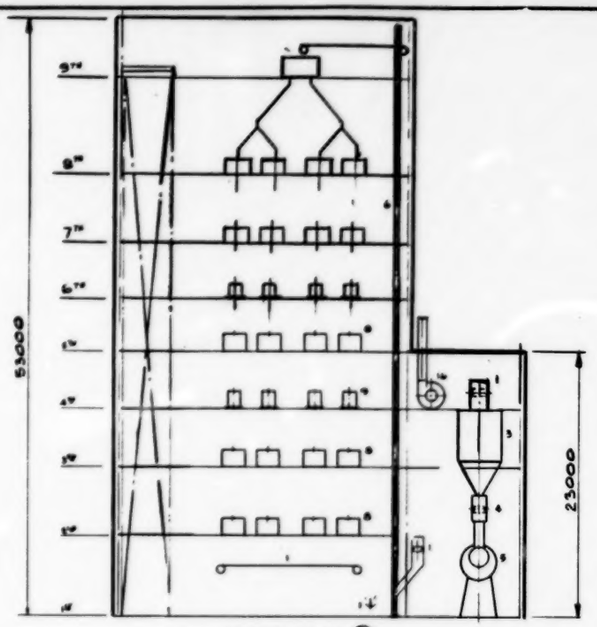
KILBORN

TITRE - TITLE

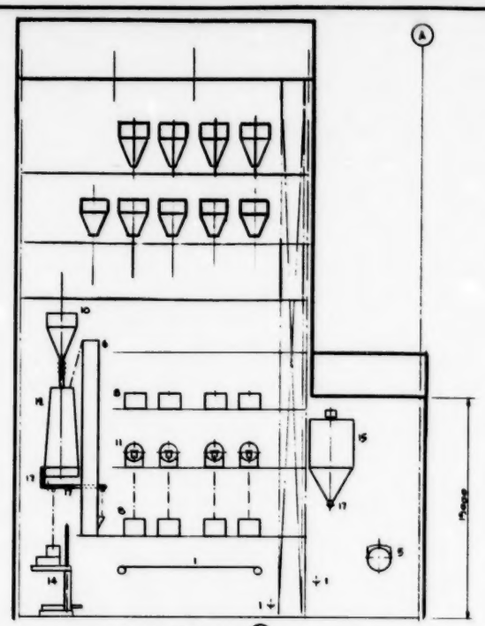
50 000 T.P.Y.
ASBESTOS ORE
DRY PROCESS MILL
GENERAL LAYOUT
PLANS

3523 | 19

10-F-02



SECTION ON COL. (3)



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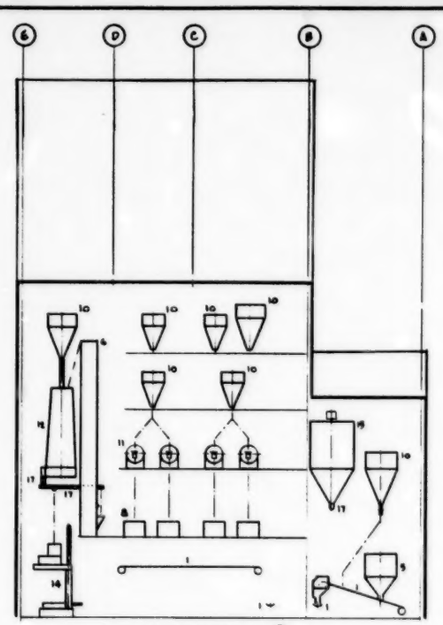
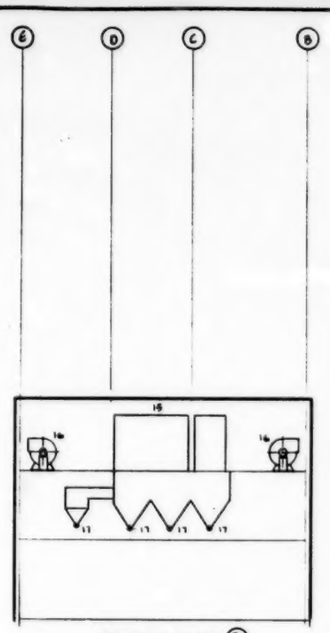


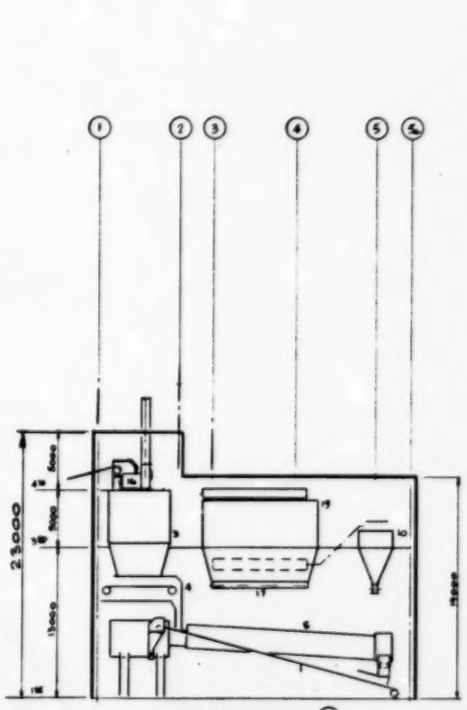
SECTION ON COL. (5)



SECTION ON COL. (5a)

EQUIPMENT LEGEND

1. BELT CONVEYOR
2. DOUBLE DECK SCREEN
3. SURGE BIN
4. BELT FEEDER
5. ROTARY DRYER
6. BUCKET ELEVATOR
7. 4-WAY DISTRIBUTOR
8. GYRATORY SCREEN
9. FIBERIZER
10. CYCLONE
11. DEDUSTER
12. PRODUCT BIN
13. TURBO FIBERIZER
14. BAGGING MACHINE
15. DUST COLLECTOR
16. FAN
17. SCREW CONVEYOR



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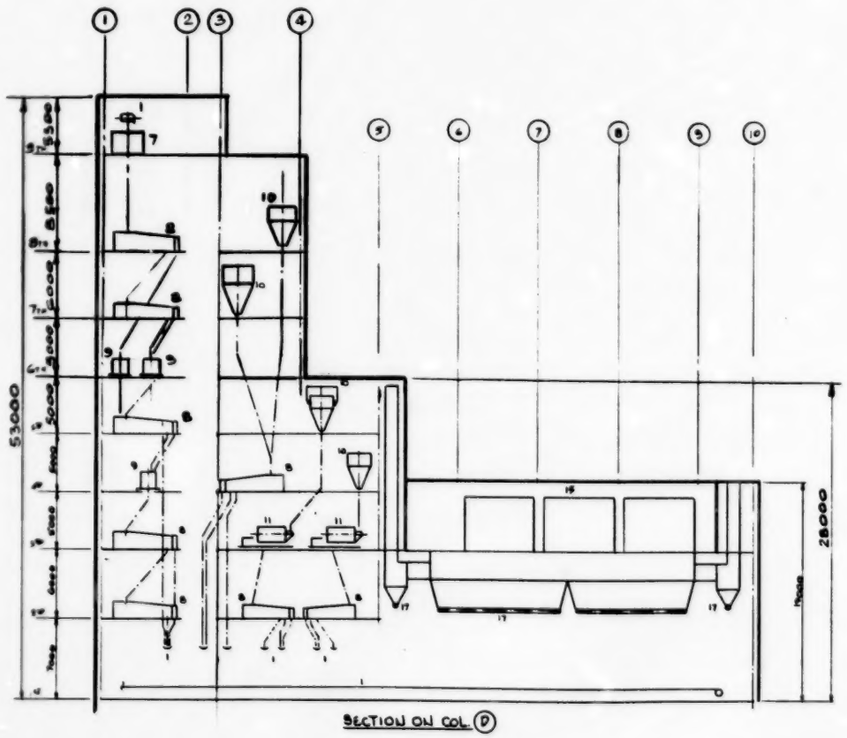
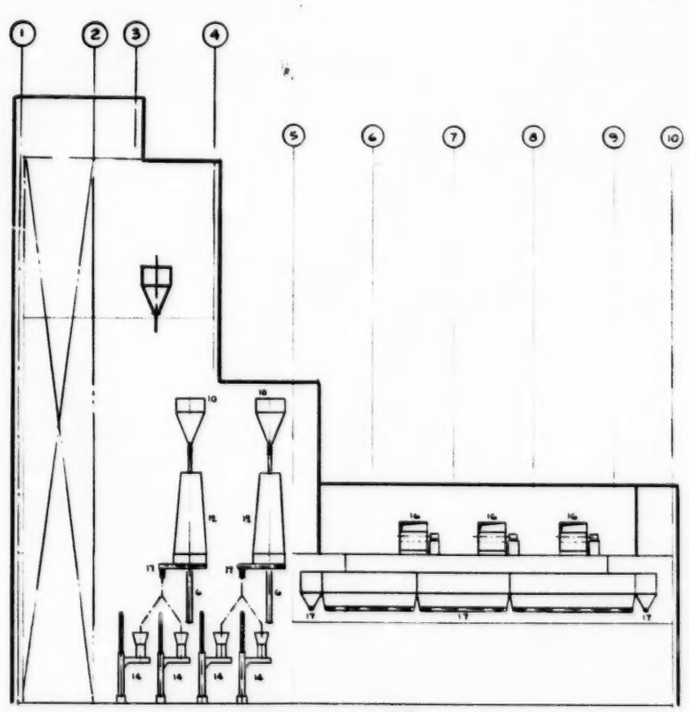


SECTION ON COL. (D)



SECTION ON COL. (E)

0 2 4 6 8 10 12 m

DESIGNED AS REFERENCE - REFERENCE DRAWINGS

SECTION GENERAL LAYOUT	CLIENT: CALUMET / LAFARGE	TITRE - TITLE: 30000 T.P.Y. ASBESTOS ORE DRY PROCESS MILL GENERAL LAYOUT SECTIONS
DRAWN: P.DESCHAMBAULT AUG 86	LOCATION:	KILBORN
		NO. LOT / D.M. NO.
		NO. PROJET / PROJECT NO: 3523
		NO. DIVISION / DIVISION NO: 19
		NO. DESSIN - DRAWING NO: 10-F-03
		REV.

KILBORN

CLIENT: CANMET / LAFARGE

PROJECT: COMPARATIVE COST STUDY — WET & DRY MILLING

AREA: DRY MILL

PROJ. No 3523 | DIV. No. 15 | AREA No. 6

ESTIMATOR ASK | CHECKED | EXTENSIONS | APPROVED

PROJECT ESTIMATE

TYPE CAMP Q.O.M | SHEET No. 1 OF 4 | ESTIMATE No. 1 | DATE 28/8/86

ACCOUNT CODE	DESCRIPTION	TYPE	QUANTITY	UNIT	LABOUR UNIT MH	LABOUR TOTAL MH	LABOUR RATE MH	LABOUR COST	MATERIAL UNIT COST	MATERIAL COST	SUB-CONTRACT UNIT COST	SUB-CONTRACT COST	TOTAL COST
100	SITE WORK:												
	EXCAVATION		1550	M^3							$10.00/M^3$		15 500
	BACKFILL		1550	M^3							$20.00/M^3$		31 000
													46 500
200	BUILDING & STRUCTURES:												
	CONCRETE & EMB. STEEL		1450	M^3							$600/M^3$		870 000
	STEEL		1050	T							$3300/T$		3 465 000
	FLOORS ETC.		6160	M^2							$45/M^2$		277 200
	ROOFING ETC.		1700	M^2							$80.75/M^2$		137 275
	SIDING		7135	M^2							$80.75/M^2$		576 125
	DOORS ETC (ALLOWANCE)												520 000
													5 845 600
300	BUILDING SERVICES:												
	ALLOWANCE												350 000
	TOTAL												

FORM KE 728 REV 1

KILBORN

PROJECT ESTIMATE

CLIENT: CANMET / LAFARGE

PROJECT: COMPARATIVE COST STUDY — WET & DRY MILLING — DRY MILL

PROJ No. 3523 | DIV No. 15 | AREA No. —

ESTIMATOR AK | CHECKED | EXTENSIONS | APPROVED

TYPE COMP 004M | SHEET No. 2 OF 4 | ESTIMATE No. 1 | DATE 28/8/86

ACCOUNT CODE	DESCRIPTION	TYPE	QUANTITY	UNIT	LABOUR UNIT MH	LABOUR TOTAL MH	LABOUR RATE MH	LABOUR COST	MATERIAL UNIT COST	MATERIAL COST	SUB-CONTRACT UNIT COST	SUB-CONTRACT COST	TOTAL COST
450	MECHANICAL EQUIPMENT :												
	BELT CONVEYOR - 900mm - 96.6 METERS LONG C/W SKIRTING, IDLERS, PULLEYS, SCRAPERS DRIVE (EXCL MOTOR)		1		1500	1500	40.00	60000		150200			210700
	BIN		1		150	150	40.00	6000		22000			28000
	BELT FEEDER (DM) C/W MOTOR		1		50	50	40.00	2000		15600			17600
	ROTARY DRYER 2.4M X 14.2M LONG C/W BURNER ROTARY FURNACE DISCHARGE MANIFOLD LOW EFFICIENCY CYCLONE, BAGHOUSE AND DUCTING FANS EL. CONTROLS EXCL. MOTOR		1		3000	3000	40.00	120000		244000			1364000
	OIL STORAGE SYSTEM & SUPPLY SYSTEM		1		250	250	40.00	10000		35000			45000
	DISTRIBUTOR - 4-WAY - C/W DRIVE EXCL MOTOR		1		100	100	40.00	4000		16000			20000
	GYRATORY SCREENS 1550 X 3000 SCREENING SURFACE C/W DECKS, DOUBLE SURFACE FEED & DISCHARGE CHUTES, SUPPORT FRAME EXCL MOTORS		32		150	4800	40.00	192000	33500	1072000			1264000
	TRIPPER ELEVATORS - 2 STAGE BELT, CAR C/W WINCH, HANDRAIL & DRIVE		2		175	2000	40.00	71000	35200	427200			501800
	E.P. EXISTING C/W FANS - FIBERGLASS DUCT, CONTROL DAMPERS MECHANISM BELLOWS MANIFOLD OF BAG SENSORS EXCL MOTOR CATWALKING CONN		1		2200	2200	40.00	88000	29600	29600			101400
	TOTAL							503000		3962500			4512100

KILBORN

CLIENT: CANMET / LAFARGE

PROJECT: COMPARATIVE COST STUDY — WET & DRY MILLING

AREA: DRY MILL

PROJ. No. 3513 | DIV. No. 15 | AREA No. —

ESTIMATOR: AK | CHECKED | EXTENSIONS | APPROVED

PROJECT ESTIMATE — TYPE: ROM | SHEET No. 3 OF 4 | ESTIMATE No. | DATE: 28/8/86

ACCOUNT CODE	DESCRIPTION	TYPE	QUANTITY	UNIT	LABOUR UNIT MH	LABOUR TOTAL MH	LABOUR RATE MH	LABOUR COST	MATERIAL UNIT COST	MATERIAL COST	SUB-CONTRACT UNIT COST	SUB-CONTRACT COST	TOTAL COST
	MECHANICAL EQUIPMENT (CONT):												
	CYCLONE COLLECTOR - UNLINED FLANGED FOR BOLT AND SLEEVE MOUNTING												
	2100 mm Ø		9		80	720	40.00	28800	14100	126900			155700
	2700 mm Ø		8		120	960	40.00	38400	17200	137600			176000
	AIRLOCK VALVES - ROTARY TYPE AND AS FLANGED FOR MOUNTING C/W DRIVES FULL MOTOR		27		INCL	INCL	—	—	6500	175500			175500
	HORIZONTAL DEDUSTERS - 900 Ø x 2500 LONG C/W REMOVABLE WEAR MOUNTING PANELS REMOVABLE COVERS REVOLVING TRANSFER PIPES MOUNTED AREAS ETC FULL MOTOR		8		180	1440	40.00	57600	26000	208000			265600
	TURBO SEPERATORS - HEAVY DUTY C/W DRIVES FULL MOTOR		9		170	1530	40.00	61200	14600	131400			192600
	BACKING RING - 10 TONNE CAP. C/W HEAVY DUTY LIFT POSITION SCREW. FLEXIBLE ARRANGE CHAIN DRIVE FULL MOTOR		2		375	750	40.00	30000	83200	166400			196400
	PRESSURE PACKING MACHINES FOR 50KG BAGS C/W HYDRAULIC UNITS - PRE COMPRESSION UNITS - AUTOMATIC WEIGHING HOPPER AND SCALE		4		1200	4800	40.00	192000	307800	1231200			1423200
	BELT CONVEYORS INSIDE MILL		12		250	3000	40.00	120000		350000			470000
	SCREW CONVEYORS		6		40	240	40.00	9600		54100			63700
	BUCKET ELEVATORS		3		90	270	40.00	10800		120000			130800
	TOTAL							548400		2701500			3249900

F190 KE 220 REV 1

KILBORN

CLIENT: CANMET / LAPALME

PROJECT: COMPARATIVE COST STUDY — WET & DRY MILLING

AREA: DRY MILL

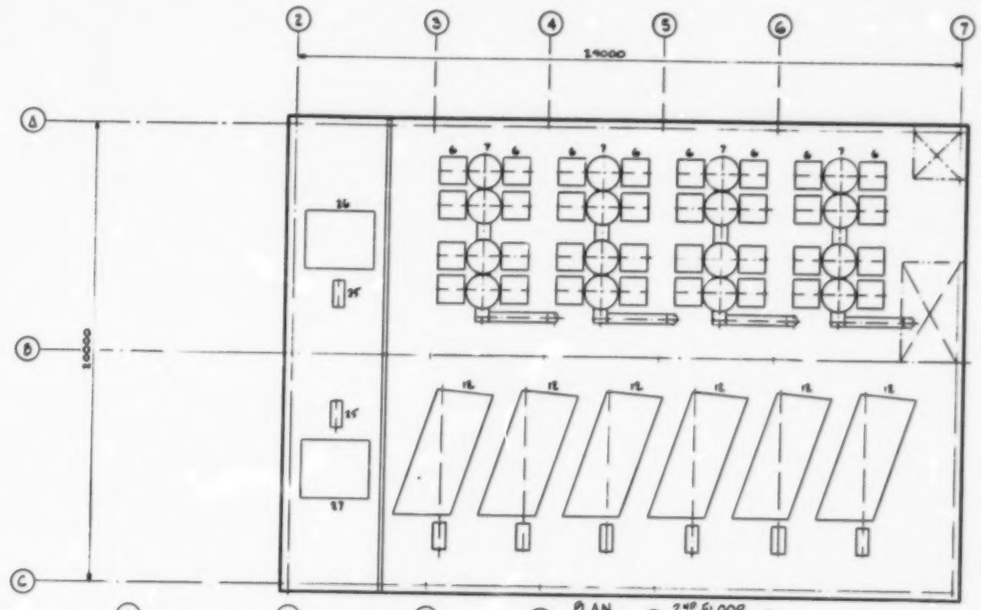
PROJ. No. 3523 | DIV. No. 15 | AREA No. —

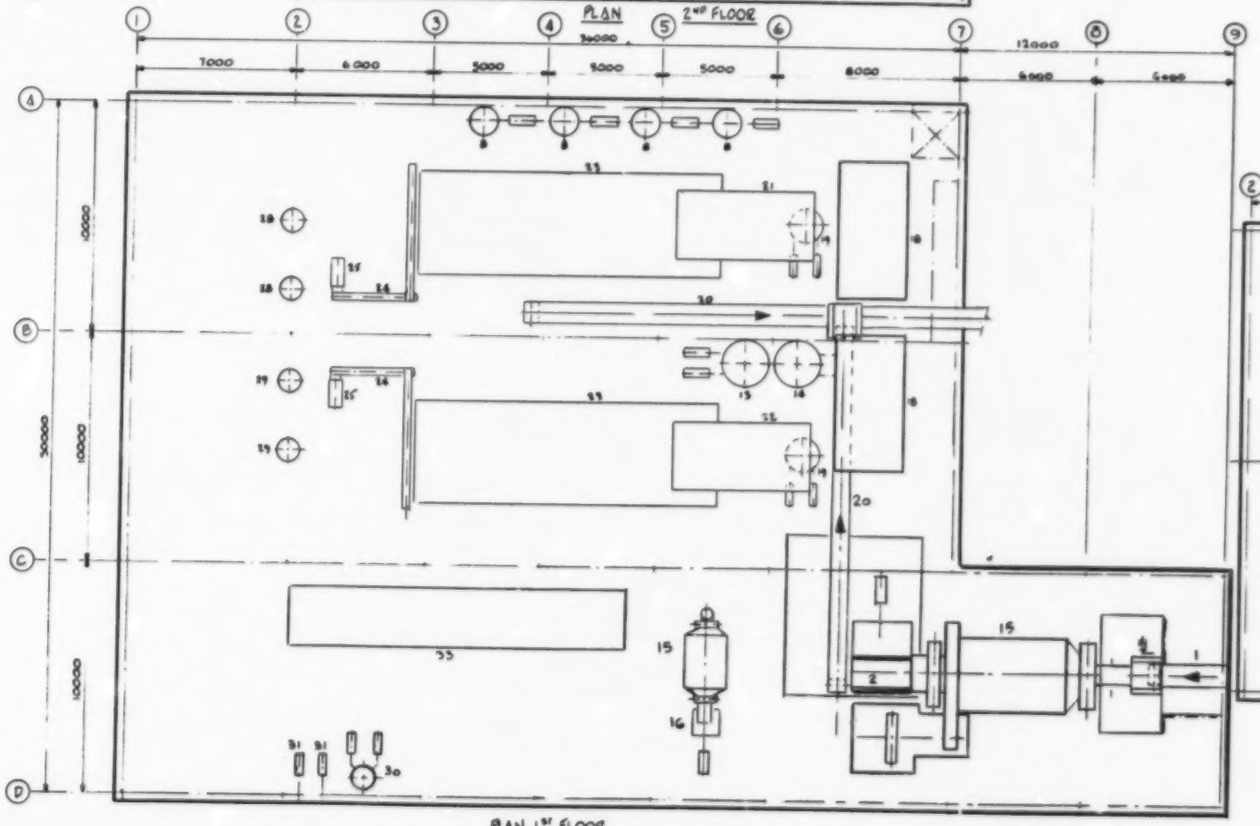
ESTIMATOR: MK | CHECKED: | EXTENSIONS: | APPROVED:

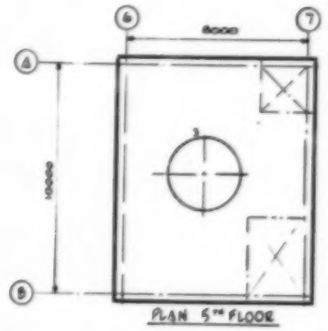
PROJECT ESTIMATE | TYPE: COMP COM | SHEET No. 4 OF 4 | ESTIMATE No. | DATE: 28/8/86

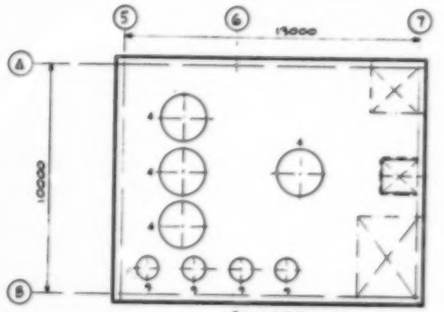
ACCOUNT CODE	DESCRIPTION	TYPE	QUANTITY	UNIT	LABOUR UNIT MH	LABOUR TOTAL MH	LABOUR RATE MH	LABOUR COST	MATERIAL UNIT COST	MATERIAL COST	SUB-CONTRACT UNIT COST	SUB-CONTRACT COST	TOTAL COST
400	MECHANICAL EQUIPMENT (CONT):												
	MOTORS		1 LOT			INCL				425 000			425 000
	CHUTEWORK COMPLETE		1 LOT			INCL						350 000	350 000
	DUCTWORK (ASPIRATION)		1 LOT			INCL						160 000	160 000
	" (ENVIRONMENTAL)		1 LOT			INCL						420 000	420 000
	LABORATORY EQUIPMENT.		1 LOT			—						110 000	110 000
						TOTAL PARTIAL (1)				425 000		1040 000	1465 000
						" " (2)		548 400		2761 100		—	3309 500
						" " (3)		563 600		3962 500		—	4526 100
								1112 000		7087 600		1040 000	9240 600
500	PROCESS PIPING (DRYER BUILDING):												30 000
600	ELECTRICAL:												600 000
700	INSTRUMENTATION:												100 000
	TOTAL												

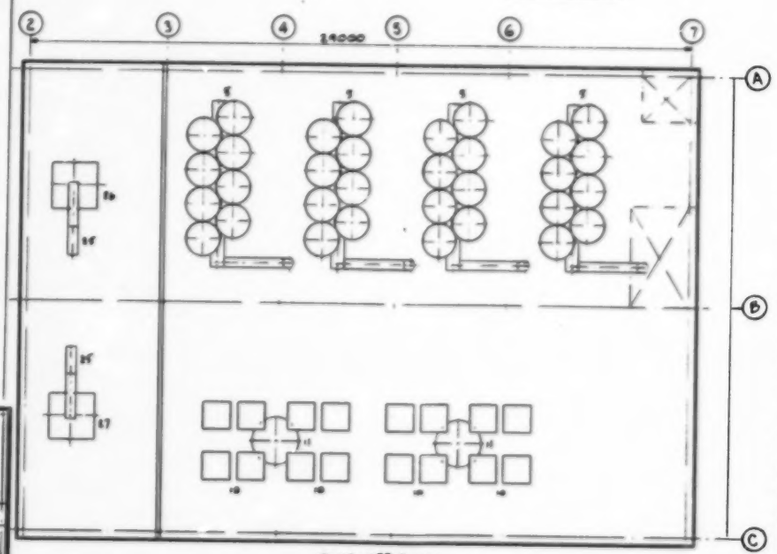
FORM KE 220 REV 1











LEGEND

1. BELT CONVEYOR (MAIN FEED)
2. DOUBLE DECK SCREEN
3. DISTRIBUTOR C/W AGITATOR
4. DISTRIBUTOR C/W AGITATOR
5. PRIMARY CONES C/W SCREW CONVEYORS
6. PRIMARY TROMMELS
7. SECONDARY TROMMELS C/W SCREW CONVEYORS
8. SECONDARY CONES OVERFLOW PUMPBOX C/W AGITATOR
9. DISTRIBUTOR
10. SECONDARY TROMMELS
11. TABLE FEED DISTRIBUTOR C/W AGITATOR
12. DEISTER TABLE
13. FILTER FEED TANK GROUP 4
14. FILTER FEED TANK GROUP 5
15. ROD MILL
16. PUMPBOX
17. SURGE BIN C/W AGITATOR
18. BELT FILTER PRESS (TAILINGS)
19. PUMPBOX
20. TAILINGS BELT CONVEYOR
21. BELT FILTER PRESS GROUP 4
22. BELT FILTER PRESS GROUP 5
23. EXTRUDER & DRYER
24. SCREW CONVEYOR
25. BUCKET ELEVATOR
26. FIBRE STORAGE BIN GROUP 4
27. FIBRE STORAGE BIN GROUP 5
28. BAGGER GROUP 4
29. BAGGER GROUP 5
30. THICKENER OVERFLOW TANK
31. THICKENER UNDERFLOW PUMPS
32. THICKENER NOT SHOWN
33. DUST COLLECTOR

0 1 2 3 4 5 6 7 m

DESSINS DE REFERENCE - REFERENCE DRAWINGS

REVISIONS

GENERAL LAYOUT

D BOYDEN

CANMET / LAFARGE

KILBORN

30,000 MTPY
MAGNESITE ORE
WET PROCESS MILL
GENERAL LAYOUT
PLANS

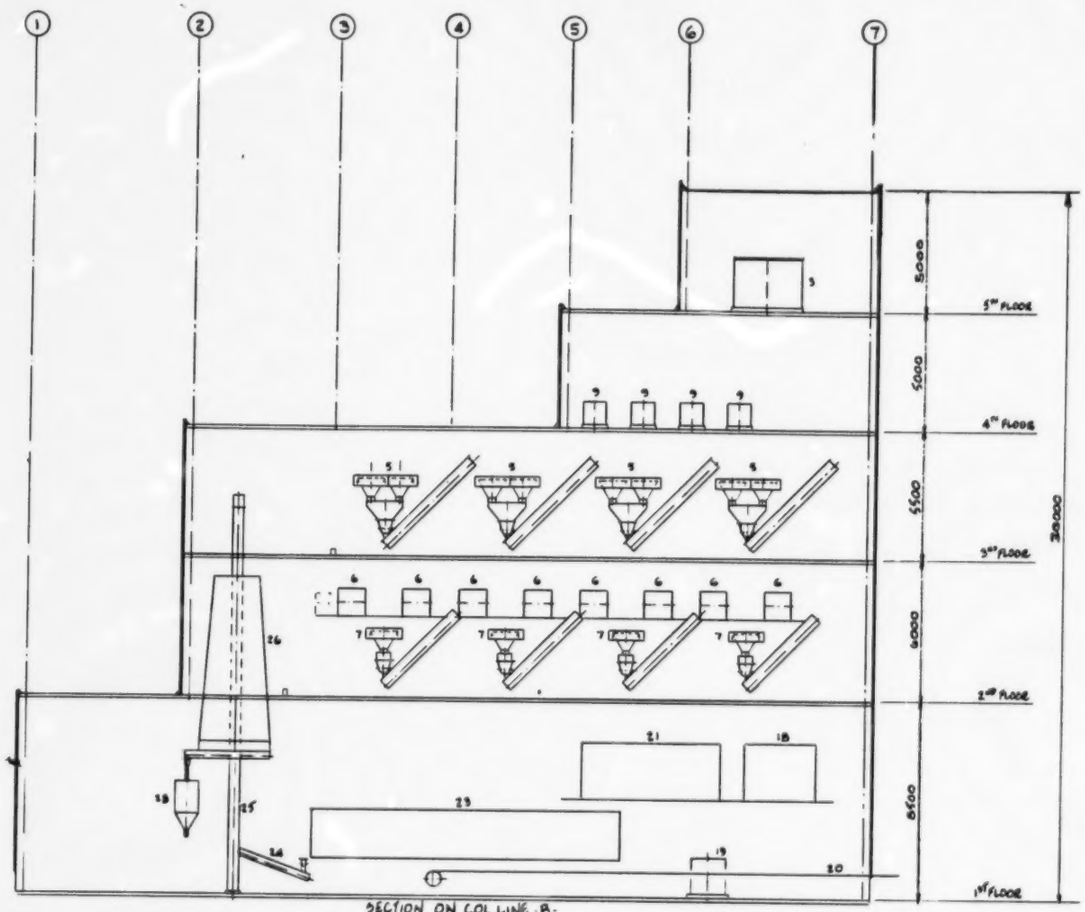
NO. SITE
BOW NO.

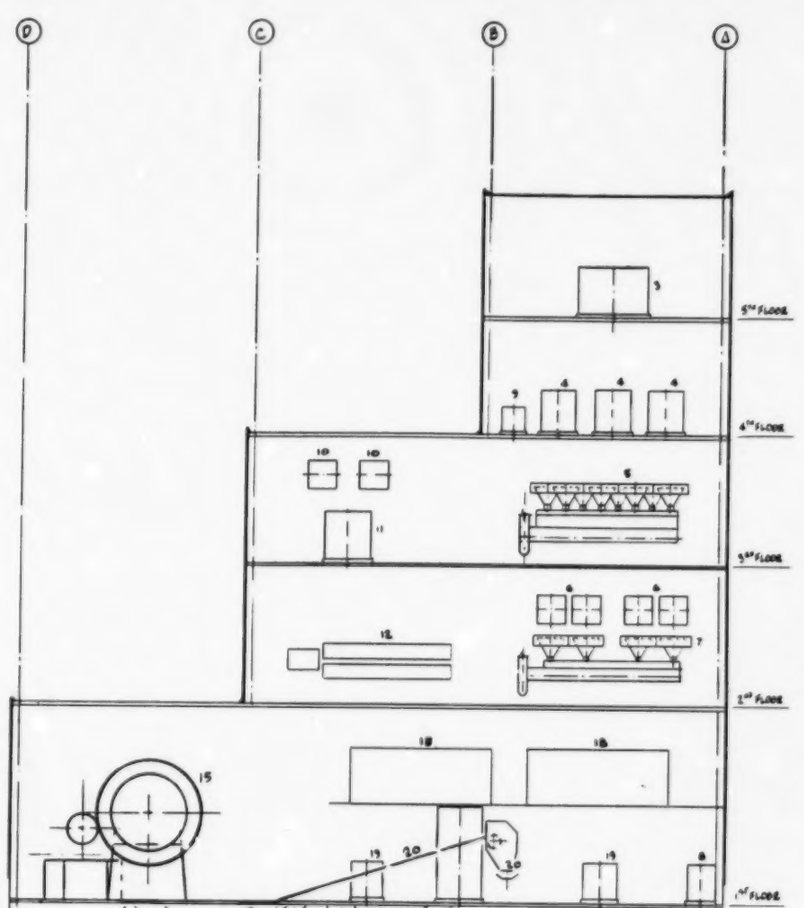
NO. PROJET
PROJECT NO. 3523

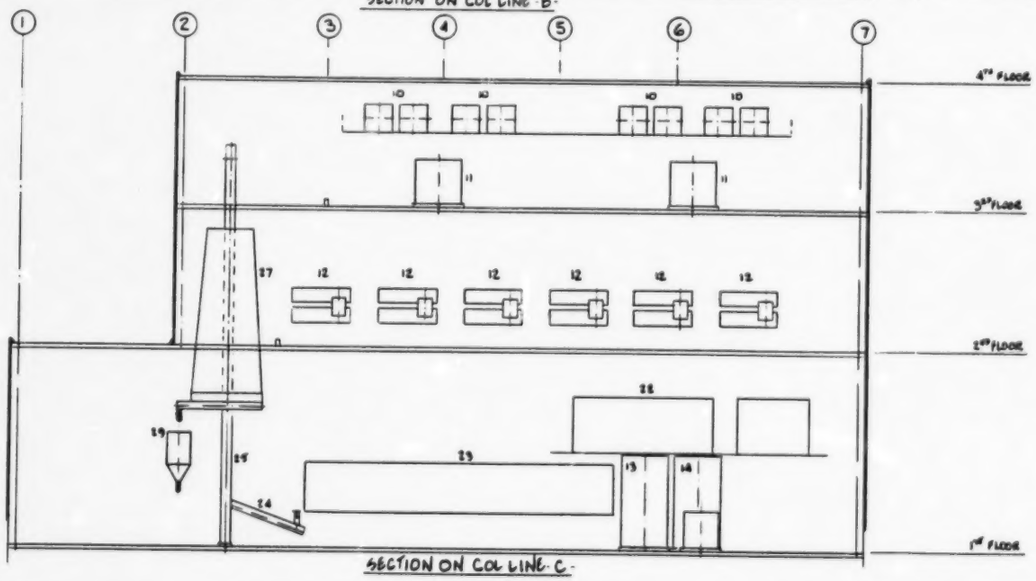
NO DIVISION
DIVISION NO. 15

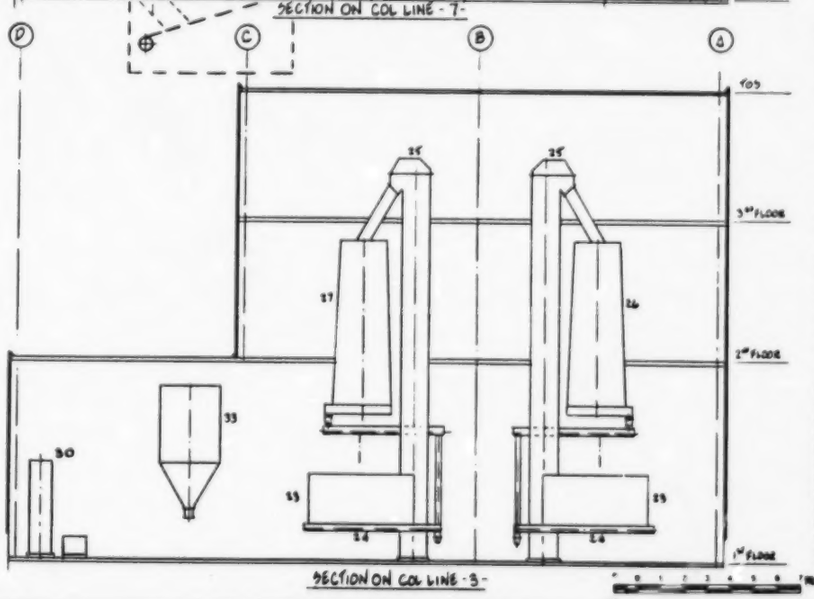
NO DESSIN - DRAWING NO
10-F-06

REV









LEGEND

1. BELT CONVEYOR (MAIN FEED)
2. DOUBLE DECK SCREEN
3. DISTRIBUTOR C/W AGITATOR
4. DISTRIBUTOR C/W AGITATOR
5. PRIMARY CONES C/W SCREW CONVEYORS
6. PRIMARY TROMMELS
7. SECONDARY TROMMELS C/W SCREW CONVEYORS
8. SECONDARY CONES OVERFLOW PUMPBOX C/W AGITATOR
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24. SCREW CONVEYOR
25. BUCKET ELEVATOR
26. FIBRE STORAGE BIN GROUP 4
27. FIBRE STORAGE BIN GROUP 5
28. BAGGER GROUP 4
29. BAGGER GROUP 5
30. THICKENER OVERFLOW TANK
31. THICKENER UNDERFLOW PUMPS
32. THICKENER HOT SHOWR
33. DUST COLLECTOR

0 1 2 3 4 5 6 M

DESCRIPTION
DESIGNS OR REFERENCE - REFERENCE DRAWINGS

REVISIONS

SECTION GENERAL LAYOUT
SCALE
DRAWN D BOYSEN 12/86
CHECKED
APP

CLIENT CONMET/LAFARGE
ENGINEER
LOCATION

KILBORN

TITLE - TITLE
30,000 MTPY
ASSESSED ORE
WET PROCESS MILL
GENERAL LAYOUT
SECTIONS

NO. J 572
E.C.M. NO.
NO. PROJECT PROJECT NO. 3523
NO. DIVISION DIVISION NO. 15
NO. DESIGN - DRAWING NO. 10-F-07
REV.

KILBORN

CLIENT: CANMET / CAMMACE

PROJECT: COMPARATIVE COST STUDY — WET & DRY MILLING

AREA: WET MILL

PROJ. No. 3123 | DIV. No. 15 | AREA No. | ESTIMATOR: MJH | CHECKED | EXTENSIONS | APPROVED

PROJECT ESTIMATE
TYPE: CAMP ROM
SHEET No. 1 OF 6
ESTIMATE No. 1
DATE: 28/8/86

ACCOUNT CODE	DESCRIPTION	TYPE	QUANTITY	UNIT	LABOUR UNIT MH	LABOUR TOTAL MH	LABOUR RATE MH	LABOUR COST	MATERIAL UNIT COST	MATERIAL COST	SUB-CONTRACT UNIT COST	SUB-CONTRACT COST	TOTAL COST
100	SITE WORK :												
	EXCAVATION (INCL. INCREMENT)		950	M^3									
	BACKFILL (INCL. INCREMENT)		950	M^3							$10.^{00}/M^3$		9500
											$20.^{00}/M^3$		19000
													28500
200	BUILDING & STRUCTURES :												
	CONCRETE & REINF STEEL (INCL. INCREMENT)		970	M^3							$600/M^3$		582000
	STEEL (INCL. INCREMENT)		410	T							$3300/T$		1353000
	FLOORS ETC.		5250	M^2							$45/M^2$		236250
	ROOFING ETC.		1200	M^2							$80/M^2$		96000
	SIDING		3024	M^2							$80/M^2$		241920
	DOORS ETC (ALLOWANCE)										-		250000
												ALLOW	15%
													2763270
300	BUILDING SERVICES :												
	ALLOWANCE												2100000
	TOTAL												

KILBORN

CLIENT: CANMET / LAFARGE

PROJECT: COMPARATIVE COST STUDY — WET & DRY MILL

AREA: WET MILL

PROJ. No. 3523 | DIV. No. 15 | AREA No. —

ESTIMATOR: AJK | EXTENSIONS: — | CHECKED: — | APPROVED: —

PROJECT ESTIMATE

TYPE: COMP. 00 M | SHEET No. 2 OF 6 | ESTIMATE No. 1 | DATE: 28/8/96

ACCOUNT CODE	DESCRIPTION	TYPE	QUANTITY	UNIT	LABOUR UNIT MH	LABOUR TOTAL MH	LABOUR RATE MH	LABOUR COST	MATERIAL UNIT COST	MATERIAL COST	SUB-CONTRACT UNIT COST	SUB-CONTRACT COST	TOTAL COST
400	MECHANICAL EQUIPMENT :												
	BELT CONVEYOR 900mm 19M C/W BELTING IDLERS, PULLEYS ENCLOSED ETC		1		250	350	40 "	14000	34000	34000			48000
	RODMILL 3.4 Ø x 4.9M C/W LINERS, 600 HP MOTOR		1		4500	4500	40 "	180000	1050000	1015000			1230000
	ROD CHARGER + ROD RACK		1		100	100	40 "	4000	15000	15000			19000
	SCREEN - VIBRATING 1500 x 3600 DOUBLE DECK C/W 22 KW SHP MOTOR CLOTH & HOPPER		1		160	160	40 "	6400	24000	24000			30400
	PUMP Ø800 x 20 M³		1		20	20	40 "	800	3000	3000			3800
	PRIMARY PUMP (+SPARE) 12x10 x 25 SRLC		2		175	350	40 "	14000	11850	23700			32200
	MOTOR 150 HP 1750 RPM		2		INCL	INCL	—	—	4345	8690			8690
	DISTRIBUTION BOX N° 1 3M Ø x 2M 14M³ CAP (INCL AGITATOR SHP)		1		85	85	40 "	3450	17200	17200			20600
	AGITATOR N° 2 3M³ CAP (INCL AGITATOR SHP)		4		55	220	40 "	8800	14000	56000			64800
	DR. HIPPLE CONES 1-32 1.2 M Ø x 1.2 M WITH DISCHARGE GATE AND OVERFLOW LAUNDERS		32		30	960	40 "	38400	3650	116800			155200
	DISCHARGE SCREWS 356 mm Ø 6 METERS 5 HP MOTOR INCL		4		45	180	40 "	6400	18750	75000			81400
	ANGLED DISCHARGE SCREW 356 mm Ø -35° 7.5 HP MOTOR INCL		4		40	160	40 "	6400	10500	42000			48400
	REJECTION WASHING TROMMEL 3.9 M Ø x 1.2 M C/W 5 HP MOTOR		32		30	960	40 "	38400	3750	504000			542400
	TOTAL							321050		1969390			2290390

FORM 48 126 REV

KILBORN

CLIENT: CANMET / CANMET

PROJECT: COMPARATIVE COST STUDY — WET & DRY MILLING

AREA: WET MILL

PROJ No: 3523

DIV No: 15

AREA No: 1

ESTIMATOR: AK CHECKED: SHEET No: 3 OF: 6

EXTENSIONS: APPROVED: ESTIMATE No: 1

PROJECT ESTIMATE

TYPE: CAMP 00M

DATE: 29/8/86

ACCOUNT CODE	DESCRIPTION	TYPE	QUANTITY	UNIT	LABOUR UNIT MH	LABOUR TOTAL MH	LABOUR RATE MH	LABOUR COST	MATERIAL UNIT COST	MATERIAL COST	SUB-CONTRACT UNIT COST	SUB-CONTRACT COST	TOTAL COST
450	MECHANICAL EQUIPMENT (CONT):												
	SECONDARY CONES (33-48) 1.2 M Ø x 1.2 M WITH DISCHARGE BOX AND OVERFLOW LAUNDERS		16		30	480	40 00	19200	3650	58400			77600
	DISCHARGE SCREWS 356 mm Ø 5HP MOTOR INCLUDED 5M		4		40	160	40 00	6400	18750	75000			81400
	ANGLED DISCHARGE SCREWS 356 mm Ø 7.5HP MOTOR INCLUDED 3 5M		4		40	160	40 00	6400	10500	42000			48400
	PUMP BOX 1-4 CAP 8M³		4		20	80	40 00	3200	3500	14000			17200
	PUMPS 1-4 323 SRL 10HP		4		20	80	40 00	3200	5000	20000			23200
	DISTRIBUTORS No 6-9 2M³ CAP		4		20	80	40 00	3200	3000	12000			15200
	SECONDARY WASHING TROMMELS 0.9M Ø X 1.8M 40M 5HP MOTOR		16		30	480	40 00	19200	15750	252000			271200
	DISTRIBUTORS No 10-11 5M³ CAP INCLUDING 5HP AGITATORS		2		65	130	40 00	5200	13150	31500			36700
	5M³ SCREENED SURGE BIN 3HP MOTORS		6		150	900	40 00	36000	45900	275400			311400
	5M³ FEED TANKS 2.5 M Ø x 2.5M C/W AGITATORS 5HP		2		80	160	40 00	6400	17500	35000			41400
	FEED TANK PUMPS 323 SIZE 5HP		4		20	80	40 00	3200	4200	16800			20000
	TOTAL							111600		432100			543700

KILBORN

PROJECT ESTIMATE

CLIENT: CANMET / LAFARGE

PROJECT: COMPARATIVE COST STUDY — WET & DRY MILLING

AREA: WET MILL

PROJ No. 3527 | DIV. No. 15 | AREA No. | ESTIMATOR AFK | EXTENSIONS | CHECKED | APPROVED

TYPE COMP STDY | SHEET No. 4 OF 6 | ESTIMATE No. 1 | DATE 29/5/86

ACCOUNT CODE	DESCRIPTION	TYPE	QUANTITY	UNIT	LABOUR UNIT MH	LABOUR TOTAL MH	LABOUR RATE MH	LABOUR COST	MATERIAL UNIT COST	MATERIAL COST	SUB-CONTRACT UNIT COST	SUB-CONTRACT COST	TOTAL COST
400	MECHANICAL EQUIPMENT (CONT)												
	ROD MILL 1200 Ø X 1800 C/W LINERS												
	150 HP MOTOR		1		200	200	40.00	8000	76000	76000			84000
	ROD CHARGER & ROD RACK		1		50	50	40.00	2000	5000	5000			
	DISCHARGE PUMPBOX 1M³ CAP		1		20	20	40.00	800	3000	3000			3800
	DISCHARGE PUMP 3X3 SRL 3HP		2		40	40	40.00	1600	4000	8000			9600
	KOMLINE-SANDERSON SCREENING PRESS HIGH PRESSURE "NIP" ROLL TYPE (SOLID MOISTURE REDUCTION TO 65% SOL)		4		300	1200	40.00	48000	265000	1060000			1108000
	DISTRIBUTOR CAP 8M³ INCL SM AGITATOR		1		55	55	40.00	2200	14000	14000			16200
	FILTRATE RECEIVING TANK 8M³		2		55	110	40.00	4400	3500	7000			11400
	FILTRATE DISCHARGE PUMP 5X4 SRL 10 HP		2		40	80	40.00	3200	5000	10000			13200
	FILTRATE DISCHARGE PUMP 5X4 SRL 15 HP		2		40	80	40.00	3200	6500	13000			16200
	THICKENER MECHANISM 25M Ø X 4M (STRUCTURE & TANK IN CODE 200)		1		800	800	40.00	32000	160000	130000			162000
	THICKENER OVERFLOW TANK (RAIN TANK) 1M Ø X 4M		1		INCL	INCL	-	-	1500	1500			1500
	OVERFLOW DISCHARGE PUMP 6X4 SRL 75 HP		2		25	50	40.00	2000	5500	11000			13000
	THICKENER UNDERFLOW PUMP 3X3 SRL 3HP		2		2	40	40.00	1600	4500	9000			10600
	TOTAL							107200		1350500			1457700

KILBORN

CLIENT: CANMET / LAFARGE

PROJECT: COMPARATIVE COST STUDY — NET F DRY MILLING

AREA: WET MILL

PROJ No 3523 | DIV No. 15 | AREA No | ESTIMATOR AJK | CHECKED | EXTENSIONS | APPROVED

PROJECT ESTIMATE
TYPE CLASS 004
SHEET No 5 OF 6
ESTIMATE No 1
DATE 29/8/06

ACCOUNT CODE	DESCRIPTION	TYPE	QUANTITY	UNIT	LABOUR				MATERIAL		SUB-CONTRACT		TOTAL COST
					UNIT MH	TOTAL MH	RATE MH	COST	UNIT COST	COST	UNIT COST	COST	
	MECHANICAL EQUIPMENT (CONT):												
	EXTRUDER DRYER BELT TYPE STEAM HEATED PROCTOR SCHWARTZ		2		450	900	40.00	36000	260.000	520000			556000
	ELECTRIC STEAM BOILER CHROMALOX MODEL KCMS 150 PSI 10,000 lbs STEAM/HR 3200 KW (4250 HP)		1		250	250	40.00	10000	105.00	105000			115000
	SCREEN CONVEYORS 3 DECK C/W STRUCTURE		4		25	150	40.00	4000	6500	26000			30000
	BUCKET ELEVATOR (17 METERS)		2		80	160	40.00	6400	35000	70000			76400
	FIBRE PELLET BINS		2		375	750	40.00	30000	8500	167000			197000
	BAGGING MACHINES		4		150	600	40.00	24000	55000	220000			244000
	TAILINGS CONVEYORS (INSIDE BUILDING) 25 H		1		400	400	40.00	16000	45000	45000			61000
	10 000 CFM DUST COLLECTING SYSTEM		3		100	300	40.00	12000	35000	105000			117000
								138400		1258000			1396400
						PAGE (4)		107200		1350500			1457700
						• (3)		111600		832000			943600
						• (2)		321000		1909900			2230900
						ADD	+	−		10			+ 10
	TOTAL							678200		5410000			6088200

FORM 11 26 REV

KILBORN

PROJECT COMPARATIVE COST STUDY — WET & DRY MILLING — PROJ. No. 3523
CLIENT CANMET / LAFARGE — DIV No. 15 — ESTIMATOR ASK — CHECKED — SHEET No 6 OF 6
AREA WET MILL — AREA No — EXTENSIONS — APPROVED — ESTIMATE No 1
DATE 29/8/06

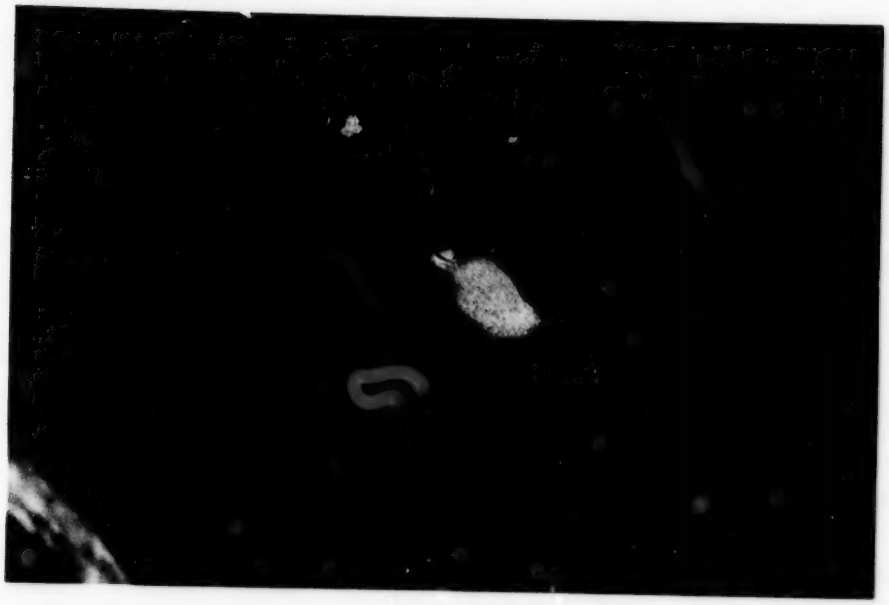
PROJECT ESTIMATE
TYPE COMP STM

ACCOUNT CODE	DESCRIPTION	TYPE	QUANTITY	UNIT	LABOUR UNIT MH	LABOUR TOTAL MH	LABOUR RATE MH	LABOUR COST	MATERIAL UNIT COST	MATERIAL COST	SUB-CONTRACT UNIT COST	SUB-CONTRACT COST	TOTAL COST
500	PROCESS PIPING :												
	ALLOWANCE (18% EQUIPMENT)												973800
600	ELECTRICAL :												
	ALLOWANCE (12% OF ELECTRICAL EQUIPMENT)												569000
700	INSTRUMENTATION :												
	ALLOWANCE (3% OF ELECTRICAL EQUIPMENT)												142300
1-	TAILINGS DISPOSAL												
	ALLOWANCE												2500000
	TOTAL												

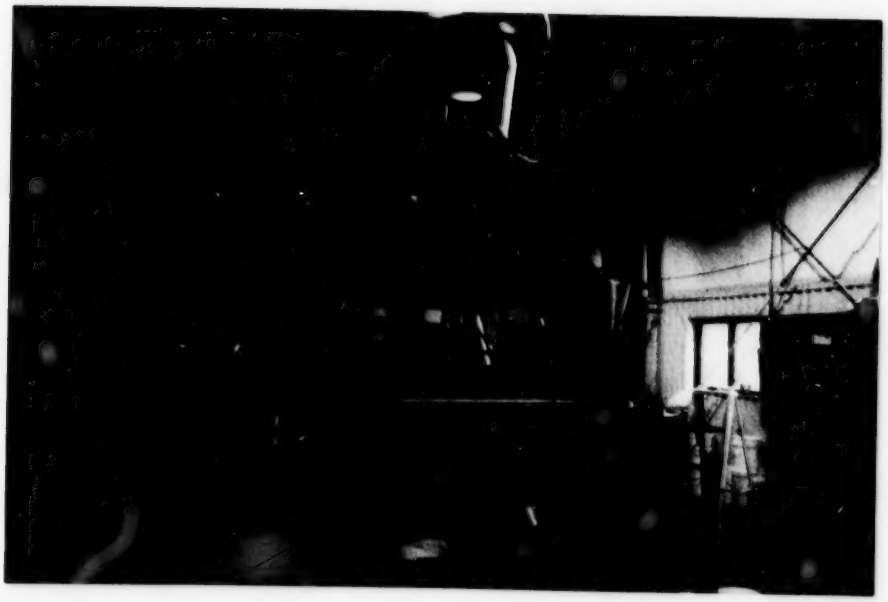
FORM AE 208 REV

WET COMMINUTION OF ASBESTOS

SIX PHOTOGRAPHS OF PILOT PLANT OPERATION

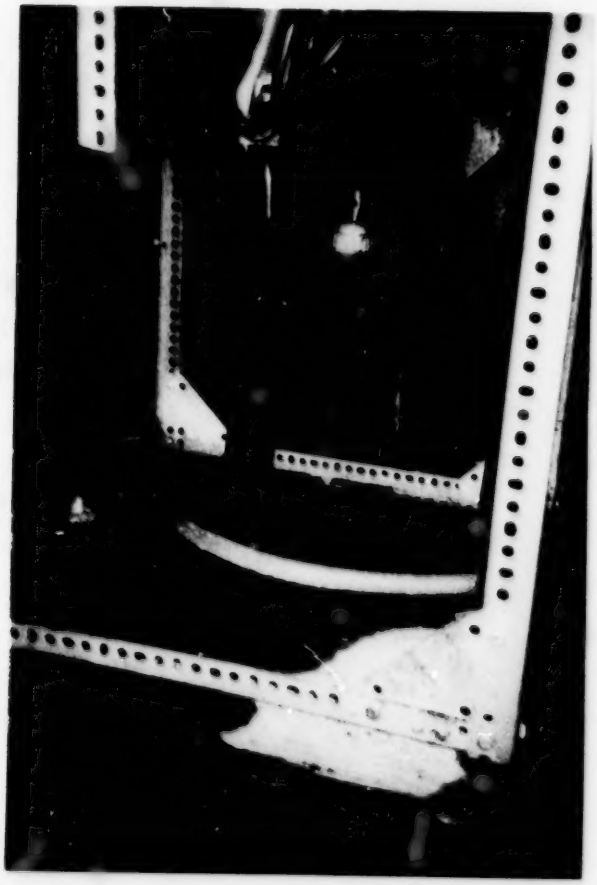


1. VIBRATING FEEDER UNDER FEED HOPPER

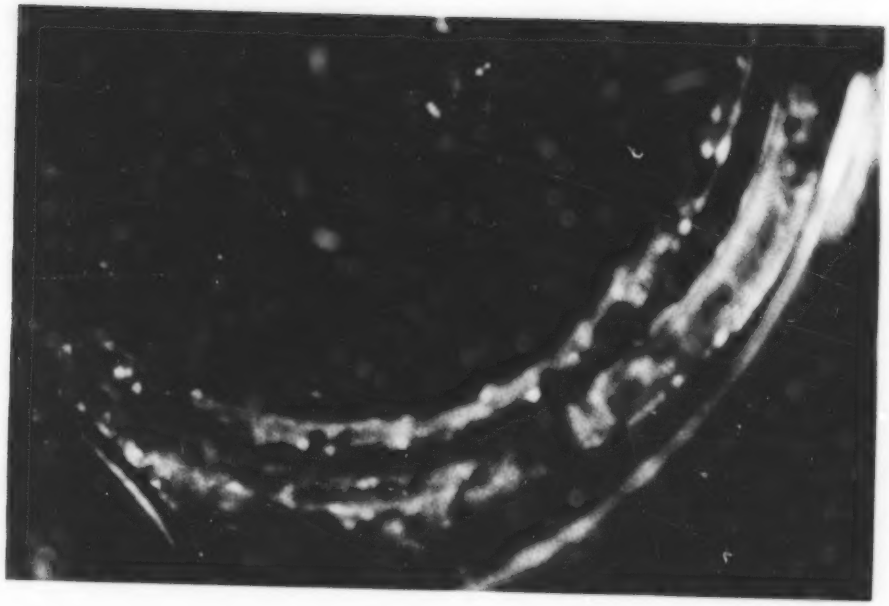


2. VIEW OF PROCESS SHOWING ELEVATED 2'Ø x 2.8' ROD MILL

3. ELUTRIATION CONES VIEWED FROM ABOVE



4. BOTTOM OF ELUTRIATION CONES



5. ASBESTOS FIBRE "ROPE" IN ROTATING TROMMEL

6. VIEW OF WILFLEY TABLE AND TROMMEL SCREEN

END